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SEPTEMBER 1950

No. 168

ASTM Bulletin

NEWS—Extensive Standardization Program Underway; 1950–1951 Publication Schedule; Technical Committees and Officers; Industrial Water and Water-Borne Waste.

Papers—Bearing Materials and Lubrication; Fungus Growth and Strength of Plastics; Testing of Aircraft Finishes; Properties of Reinforced Brick Masonry; Test for Specific Heat of Thermal Insulating Materials.

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ASTM BULLETIN

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TESTING MATERIALS

This Issue Contains

Publication Schedule for 1950–1951; New A.S.T.M. Publications.....6–12

Industrial Water and Water-Borne Industrial Waste, *by Max Hecht*..... 31

Investigation of Bearing Materials Under Various Degrees of Lubrication in the Low-Speed Range, *by Louis A. Nowell, Jr.*..... 47

Effect of Fungus Growth on the Tensile Strength of Polyvinyl Chloride Films Plasticized with Three Plasticizers, *by Sigmund Berk*..... 53

Laboratory Testing of the Rain Erosion Resistance of Aircraft Finishes, *by Jack K. Grace and George C. Frey*..... 56

Some Properties of Reinforced Grouted Brick Masonry, *by Norman W. Kelch*.. 67

A Proposed Method of Test for Specific Heat of Thermal Insulating Materials, *by Norman H. Spear*..... 79

Discussion of a Paper on Tests for Air-Entraining Agents in Concrete..... 82

NEWS ABOUT THE SOCIETY AND ITS COMMITTEES:

New Publications—Pozzolans, Soil-Testing Procedures, Application of Statistics, Electron Micro-structure of Steel, Index to Standards, Radiography.....10–12

A.S.T.M. Activity in the Field of Building Codes..... 13

Personnel of Board of Directors; 50-Year Membership Acknowledgment; National Fuel Exchange Groups.....14, 15

Schedule of A.S.T.M. Meetings; Note of Appreciation..... 16

Letters on Changing Standards Approval System..... 17

Warrick and Dyktor to Speak at October Columbus Meeting..... 18

Technical Committees Push Standardization Projects.....19–30

Work on Titanium; Radiographic Testing Recommendations..... 30

Article on Committee D-19.....31–33

25 Years on the A.S.T.M. Chain Gang..... 33

Manhattan Bus Terminal; Brooklyn-Battery Tunnel.....35, 36

List of Technical Committees, Chairmen and Secretaries.....38–41

Appointments; Personals; New Members; Necrology.....43–46

MISCELLANEOUS NEWS NOTES:

Book Reviews: Colorimetry; Bitumens; Metals at Elevated Temperatures; Resistance Welding; Acceptance Sampling; Inspection Methods; Statistical; IME Proceedings; Properties of Refrigerants; Chemical Engineers' Handbook; Fire and Codes.....41, 42

Lost Microscopes..... 38

Fuel Immersion on Plastics, Spectrographic Standards, Low Temperature Silicone Rubbers, Shortage of Engineers Forecast, Betatron Laboratory.....39, 40

Notes on Laboratory Supplies—Catalogs and Literature; Instrument Notes.....84, 85

Schedule of Other Society Meetings 43

Index to Advertisers..... 103

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SEPTEMBER—1950

No. 168

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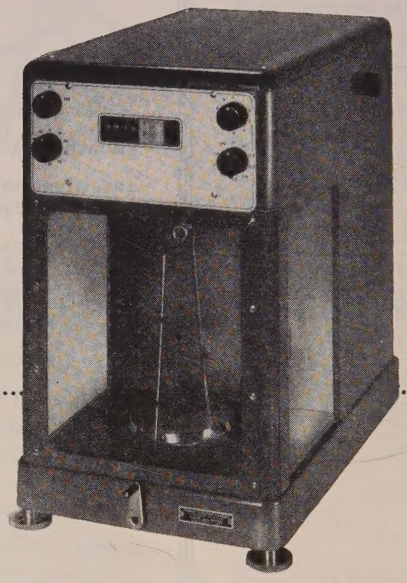

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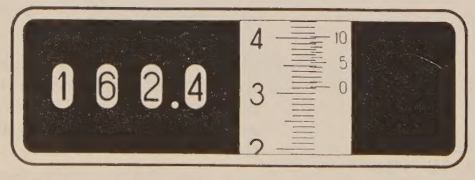

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romotion of Knowledge of Materials of Engineering, and Standardization of Specifications and Methods of Testing"

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mber 168 SEPTEMBER, 1950

Standards Committee Accepts Recommendations on New and Revised Tentatives

Approvals on Metallic Materials, Building Stone, Petroleum Products, Bituminous Materials, and Adhesives

A NUMBER of approvals ve been made by the Administrative mmittee on Standards, of recomndations presented by some of the hnical committees. The accomhying table lists these approvals, he of which are on tentatives issued the first time.

etallic Materials:

The Joint Committee on Effect of mperature looks to A.S.T.M. to apve and publish its recommendations standards. This committee is ntly sponsored by A.S.T.M. and S.M.E.

The first of various proposed standl tests and recommendations, which l come from the Joint Committee in intensified program, is a tentative ommended practice for conducting he-for-rupture-tension tests. The actice covers the essential requirents of testing machines and test thod for measuring the fracture time metallic materials—the time for frace to occur under constant tensile ds at constant temperature. The pture test is one of the most widely cticed methods for evaluating highmperature properties of metals. It s developed in a panel on gas turbine terials through a special section ich includes leading authorities of is field and was referred subsequently the Joint Committee for approval.

ilding Stone:

The Standards Committee has apved a new tentative—Test for Abrae Resistance of Stone Subjected to ot Traffic. The method follows a g trial period at the Bureau of Standds and elsewhere, during which the ar resistance of walkway surfaces of ne or other hard materials was dermined. This test has also been used by several Government departments.

Petroleum Products:

The Standards Committee has approved several recommendations submitted by Committee D-2 on Petroleum Products and Lubricants.

The first of these is a proposed tentative method of gaging petroleum and petroleum products. It was developed over the past two years by Section A on Gaging Procedure of Division II on Measurement and Sampling. It will be included in an "A.S.T.M. Manual on Measuring and Sampling Petroleum and Its Products," which will be the first volume of a projected set of oil measurement standards.

A companion standard, Tentative Recommended Practice for Volume Calculations and Corrections in Measurement of Petroleum and Petroleum Products, has also been prepared by the same group and it will also appear in the manual.

Two other tentatives, Method of Measuring the Temperature of Petroleum and Petroleum Products, and Method of Sampling Petroleum and Petroleum Products, have been developed over the same period by Sections C on Temperature and F on Sampling, respectively. Along with the two previously mentioned standards these last tentatives will be included in the new manual.

The Standards Committee has approved a revision in Tentative Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96–47 T), the revision incorporating several changes in procedure which have been made to simplify the operating technique. The changes were worked out by Section B on Extraneous Material of Research Division V on Analysis of Fuels. D 96 in its newly revised form will be included in the manual on measuring and sampling petroleum.

Actions of A.S.T.M. Administrative Committee on Standards, May and June, 1950

New Tentatives

Methods of:
- Test for Abrasive Resistance of Stone Subjected to Foot Traffic (C 241–50 T)
- Sampling Petroleum and Petroleum Products (D 270–50 T)
- Test for Consistency of Adhesives: Method A: Cup Method (D 1084–50 T)
- Gaging Petroleum and Petroleum Products (D 1085–50 T)
- Measuring the Temperature of Petroleum and Petroleum Products D 1086–50 T)

Recommended Practice for:
- Volume Calculations and Corrections in Measurements of Petroleum and Petroleum Products (D 1087–50 T)
- Conducting Time for Rupture-Tension Tests of Metallic Materials (E 85–50 T)

Revision of Tentatives

Methods of:
- Test for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96–50 T)
- Test for Resistance of Adhesive Bonds to Chemical Reagents (D 896–50 T)

Are you interested in?: New Standards—p. 5; Publication Program—p. 6; New Publications—p. 10; Standardization Activities—p. 19; Bearing Materials and Lubrication—p. 47; Fungus Growth and Plastics—p. 53; Aircraft Finishes—p. 56; Reinforced Brick Masonry—p. 67; Specific Heat of Thermal Insulating Materials—p. 79.

Adhesives:

The Standards Committee has approved a Tentative Method of Test for Consistency of Adhesives by a cup method. This is the first of several consistency tests expected to be standardized for adhesive testing.

The committee has also accepted a revision of Tentative Method of Test for Resistance of Adhesive Bonds to Chemical Reagents (D 896–46 T). The method as revised includes a screening test which will minimize test work involved in the method.

Publication Schedule for 1950—1951

Includes Supplements to Book of Standards, Special Compilations, Chemical Analysis of Metals, Special Publications

THE publication schedule of the Society continues to grow each year as is evidenced by the number of publications listed below. In addition to the regular publications—Supplements to the Book of Standards, Methods of Chemical Analysis, *Proceedings*, Index to Book of Standards, and the Year Book—and the special compilations of standards, there are a great many symposiums and special publications to be published within the next few months.

Regular Publications

1950 Supplement to Book of Standards:

The plan of issuing the Book of Standards triennially marks 1950 and 1951 as Supplement years. The 1950 Supplements to the 1949 Book of Standards will be issued in six parts in heavy paper covers. They will include the new and revised standards and tentatives adopted or accepted at the 53rd Annual Meeting or by the Administrative Committee on Standards, and will aggregate some 2000 pages.

1950 Proceedings:

Again it is expected the *Proceedings* will be a sizable volume, namely, around 1200 pages. In addition to the committee reports and technical papers presented at the 1950 Annual Meeting, the *Proceedings* will contain some of the papers presented at the First Pacific Area National Meeting held in San Francisco, Calif., last October. The papers presented at the Annual Meeting as a part of the special symposiums will appear as separate symposium publications.

Methods of Chemical Analysis of Metals:

The 1949 Book of Standards does not include the A.S.T.M. methods pertaining to Chemical Analysis of Metals. These methods will be published in a separate volume as the 1950 Book of A.S.T.M. Methods of Chemical Analysis of Metals. The previous book of chemical methods was published in 1946. It is expected the 1950 Book of Chemical Analysis will be available around November, and should comprise about 500 pages.

1950 Index to A.S.T.M. Standards:

With the continually increasing number of standards and tentatives, the value of the combined index of standards and tentatives grows. This is particularly significant in Supplement years in view of the increased number of standards books. Publication of this 1950 edition is scheduled for February, and will aggregate 250 pages. See p. 12; this BULLETIN.

1950 Year Book:

The Year Book, containing a list of the complete membership and official company-member representatives (name, title, address, company, etc.), and a list of geographical distribution of members as well as personnel of all A.S.T.M. committees, is furnished to members on request. The 1950 book should aggregate 575 pages and is scheduled for distribution early in October.

Special Compilations of Standards

The tabulation given below of special compilations of standards should be viewed as approximate only. There are so many factors affecting these books that it is not possible to give any accurate estimate of size or the date that they may become available. The size is affected by committee recommendations which may be submitted through the Administrative Committee on Standards and the date of issue is governed somewhat by editorial considerations and also to a great extent by the tremendous printing load. An innovation this year is the publication of supplements to a number of compilations of standards recently issued so as to bring these up to date without republishing the complete compilation.

Soils for Engineering Purposes:

This book, on which extensive work has been under way for the past year, will include not only all the A.S.T.M. standards pertaining to soils, but many proposed methods which are published as information and to elicit comments. A major portion of the book is devoted to these procedures, which were submitted through the effort of Committee D-18. The book thus will give a rather complete picture of methods of determining and evaluating various properties of soils, those that have been standardized as well as many others that are in use or under study. It is now available and is discussed more fully in a separate article in this BULLETIN (see page 10).

Special Technical Publications, Symposiums, etc.

The following symposiums featured as part of the 1950 Annual Meeting will be published separately with discussion.

1950 Annual Meeting Symposiums:

- Symposium on Effect of Sigma Phase on the High-Temperature Properties of Metals
- Symposium on Corrosion of Gas Turbine Materials at Elevated Temperatures
- Symposium on Methods of Testing Soils Under Triaxial Loading (this book will also include the papers on triaxial testing which were presented at the First Pacific Area National Meeting held in San Francisco, Calif., on October 10, 1949)
- Symposium on Identification and Classification of Soils
- Symposium on the Role of Nondestructive Testing in the Economics of Production

Symposium on Use of Pozzolanic Materials in Mortars and Concretes:

The papers in the symposium present the most complete picture of the state of this important subject of the use of pozzolanic materials that has hitherto been assembled in one group. The symposium was given at the time of the First Pacific Area National Meeting held last October. Copies are now available and the book is discussed in greater detail in another article in this BULLETIN (see page 10).

pers on Radiography:

The papers comprising this publica-n deal with progress in the develop-nt and application of electrostatic d betatron-type X-ray generators erating at potentials above the niliar one-million volt range, de-lopment and application of an X-ray chine for studying material and gineering parts in motion, and prog-s in technique. This symposium s held at the Annual Meeting in 1949 d a more detailed description of the ok is given in this BULLETIN (see ge 12). Copies of this publication e now available.

mposium on Rapid Methods for the Identification of Metals:

In view of the wide usefulness of pid methods for the identification metals, a symposium on this subject s held at the 1949 Annual Meeting vering discussions of the general inciples involved in the various types methods in current use and also scussion of specific applications of pid identification methods to par-ular classes of metals and alloys. is expected that this symposium will available in November. The papers mprising this symposium are as lows:

Introduction—L. A. Wooten
Development, Present State, and Out-look of Spot Test Analysis—F. Feigl
Electro Spot Testing and Electrog-raphy—H. W. Hermance and H. V. Wadlow
Instruments for Rapid Metal Identi-fication—R. R. Webster
Separating Alloys by Relative Spot Tests—H. Kirtchik
Rapid Methods for the Identification of Copper-Base Alloys—R. P. Nevers
Rapid Identification of Metal Finishes—A. Lewis and D. R. Evans
Examination of Plated and Protective Coatings by Electrographic Analysis—N. Galitzine and S. E. Q. Ashley
A Field Test Kit and Procedure for Use in the Rapid Identification of Some Nickel Alloys and Stainless Steels—H. B. Lea
Rapid Tests for Identifying Alloy Steels—E. C. Kirkham

mposium on Ultrasonic Testing:

This symposium is based on a theme ade up of the following points: (1) rasonic testing is being used very tensively today, (2) ultrasonic testing practical and is being applied in-ligently by engineers in all branches d in a variety of industries, (3) it is t just another device for throwing t more material; it can and will aid d abet manufacturing, and (4) stand-d equipment is available which will rform very acceptably in the hands of nontechnically trained people of ordinary skill. This symposium is scheduled for publication in November. The titles of the papers comprising this symposium are listed below. Most of these papers were presented at the 1949 Annual Meeting.

Basic Principles of Practical Ultrasonic Testing—J. C. Smack
Ultrasonics in the Heavy Forging Industry—J. C. Hartley
The Application of Ultrasonics to the Fabrication of Aluminum—J. V. Carroll
Ultrasonic Testing in Railroad Work—E. D. Hall
Ultrasonics in the Electrical Industry—D. N. Kelman
Ultrasonic Testing of Bronze Forgings and Ingots—A. Piltch
Inspection, Processing, and Manufacturing Control of Metals by Ultrasonic Methods—C. H. Hastings and S. W. Carter
Ultrasonic Wave Propagation in Materials: A Guide to Theoretical Aspects—Louis Gold

Papers on Plasticity and Creep of Metals:

The publication comprises four papers which were presented at the First Pacific Area National Meeting last fall. One paper deals with super alloys which have been popularized with the advent of the jet engine. Their development has been based on the need for alloys to withstand extreme stresses in the high-temperature components of gas turbines. Another paper describes the creep data available at the present time and discusses the limitations in interpolation and extrapolation of the data. It indicates the types of additional data which would be of greatest usefulness in the design problems confronting designers in the use of metals for high-temperature service. A third paper dealing with application of forming criteria to production problems covers deep drawing, bending, shrinking, stretching, and general considerations, including loss of generalized stress and strain and of fracture, principles of dimensional similarity, and classification of parts and forming operations. A fourth paper points out that the development of experimental data suitable for allowing a choice to be made among various theoretical possibilities has not kept pace with the development of mathematical theories of plastic behavior. This publication is scheduled to appear in September. Titles of the papers are as follows:

Experimental Exploration of Plastic Flow in Sheet Metals—L. R. Jackson and W. T. Lankford
Forming Parameters and Criteria for Design and Production—William Schroeder
Use of Creep Data in Design—H. C. Cross and L. R. Jackson
Super Creep-Resistant Alloys—J. W. Freeman, D. N. Frey, E. E. Reynolds, and A. E. White

Papers on Wood:

The papers in this publication were presented at the First Pacific Area National Meeting last October. One of the papers covers studies which were conducted to get data on the relations between strength properties of glued laminated structural members and the factors affecting the strength of such members, in order to establish recommendations for design procedures. Two of the papers dealt with Douglas fir, one consisting essentially of a collection of data on standard tests of small clear specimens of virgin-growth Douglas fir and for second-growth Douglas fir of 60-yr. and 90-yr. classes; the other, a discussion of a few of the more important properties of old-growth Douglas fir which has been infected with white spot. Tests included in this study were static bending, compression parallel to grain, compression vertical to grain, shrinkage, hardness, and nail holding power. A fourth paper covered studies made on the mechanical properties of second-growth redwood and comparison with virgin timber. Announcement will be made later of how these papers are to be published.

Studies of the Strength of Glued Laminated Wood Construction—A. L. Freas
Physical and Mechanical Properties of Second-Growth Douglas Fir—J. B. Alexander
Strength and Related Properties of Old-Growth Douglas Fir Infected with Fomes Pini—J. R. Stillinger
Mechanical Properties of Second-Growth Redwood and Comparison with Virgin Timber—Emanuel Fritz

Symposium on Measuring Viscosity at High Rates of Shear:

Some time ago Subcommittee V on Analysis of Fuels of A.S.T.M. Committee D-2 on Petroleum Products and Lubricants was requested to develop a method for measuring viscosity at rates of shear up to 1,000,000 reciprocal seconds. Interest in the subject stemmed from the fact that the use of additives of various types in lubricants and fluids was increasing rapidly and that the resultant viscosities of such products might vary with use in which case the values obtained in conventional equipment might not indicate their performance in use. The subcommittee's attention was called to the existence of two test methods which looked very promising. One of these was the Kingsbury tapered plug (shear in a

simulated bearing) instrument which had been used by S. J. Needs in his studies; results from it should bear some relationship to bearing performance. The other one had been in use at Pennsylvania State College by Prof. Fenske in his study of hydraulic liquids. In this case capillaries are used to measure viscosities. Papers were prepared by Messrs. Fenske and Needs and presented at a meeting of Committee D-2 held in Washington last February. This material is scheduled for publication in October.

Supplement to Metal Cleaning Abstracts:

This supplement to the bibliography of "Metal Cleaning" brings the bibliography up to date and supplements the book published last year by 165 references. The book published last year consolidated all previous material and also contained a large group of additional references and several indexes. The supplement will be available around November.

1949 Supplement to Bibliography on Electrical Contacts:

The 1949 Supplement to the Bibliography on Electrical Contacts which publication includes extensive abstracts, is the sixth Supplement to the original Bibliography issued in January, 1944. This publication, including its Supplements, is really a monumental one and is of outstanding service to all those concerned with this field. The supplement is scheduled for publication in September.

1950 Marburg Lecture—Chemical Spectroscopy:

The excellent and informative lecture on "Chemical Spectroscopy" given by Dr. Wallace R. Brode of the National Bureau of Standards at the 1950 Annual Meeting will be available around December. It will also appear in the 1950 *Proceedings*. Dr. Brode discusses the development and use of spectroscopic methods in analytical control. The use of both emission spectra and absorption spectra procedures are outlined and the method limitations indicated. In colorimetry and color description, the application of these methods is considered as well as the use of spectrophotometer procedures in infrared and ultraviolet regions of the spectrum. Part of the lecture is devoted to the field of emission spectroscopy, including the development of rapid analysis procedures and the recent advance in photoelectric recording instruments.

COMPILATIONS OF STANDARDS.

Committee Sponsoring	Title	Approximate Number of Pages	Approximate Publication Date
B-1	Wire for Electrical Conductors	230	Dec.
B-5	Copper and Copper Alloys	510	Dec.
D-2	Petroleum Products and Lubricants	780	Nov.
D-3	Gaseous Fuels	150	Dec.
D-11	Rubber and Rubber-Like Products	670	Jan.-Feb.
D-13	Textile Materials	580	Oct.
D-18	Procedures for Soils	434	Aug.
	Supplements to Compilations		
C-1	Cement	...	Oct.
D-1	Paint, Varnish, Lacquer, and Related Products	...	Nov.
D-9	Electrical Insulating Materials	...	Dec.
D-20	Plastics	...	Jan.

Report on Standard Samples for Spectrochemical Analysis:

Quantitative spectrochemical analysis is based on comparison of unknown samples with standard samples of similar composition. Standard samples are frequently prepared by the analyst for the particular problem in hand, but for the analysis of many common materials, particularly metals and alloys standard samples have been prepared in quantities adequate for general distribution. The rapid growth of spectrochemical analysis and a corresponding increase in available standard samples call for a periodic compilation of types of sources of standards for the information of analysts.

In 1943 a report on available standard samples was prepared under the sponsorship of the War Metallurgy Committee by W. R. Brode. The report was revised by W. R. Brode and B. F. Scribner and published in October, 1944. Since then, Subcommittee IV on Standards and Pure Materials of Committee E-2 on Emission Spectroscopy has undertaken to keep the report up to date. A revision was published in 1947 and now the results of a new survey are published to provide in a form for ready reference current information on spectrochemical standard samples. The report should be available in October.

Procedures for Emission Spectrochemical Analysis:

Due to recent advances in emission spectroscopy, the variety of apparatus and techniques currently in use has become so large as to preclude standardization to the point that would enable the committee to write tentative methods. It was felt that the best approach to the problem was the collection of procedures that are currently being used. The committee has now completed the collection and preparation for publication of some 50 suggested methods for emission spectrochemical analysis, covering a wide range of materials and techniques. It is planned to publish these methods as a compilation which will be available around February.

X-Ray Diffraction Data Cards Index:

An index is being prepared for the new X-ray diffraction cards which index is to be in two sections: (1) a numerical listing and (2) alphabetical listing. The book will occupy 900 pages and will be furnished to each purchaser of the X-ray cards. It will be bound in cloth and is expected to be available in November.

Standards for Students in Engineering:

A new compilation of standards and related data for use in technical school courses involving materials of engineer-

LIST OF PENDING PUBLICATIONS.
(Discussed in Detail in Accompanying Article.)

Regular Publications

1950 Supplement to Book of Standards
1950 Proceedings
Methods of Chemical Analysis of Metals
1950 Index to A.S.T.M. Standards
1950 Year Book

Special Compilations

Wire for Electrical Conductors
Copper and Copper Alloys
Petroleum Products and Lubricants
Gaseous Fuels
Rubber and Rubber-Like Products
Textile Materials
Soils for Engineering Purposes
Supplements to Compilations:
Cement
Paint, Varnish, Lacquer, and Related Products
Electrical Insulating Materials
Plastics

Technical Publications and Papers

Marburg Lecture
Supplement to Metal Cleaning Abstracts
1949 Supplement to Bibliography on Electrical Contacts
1950 Appendix to A.S.T.M. Manual of Engine Test Methods for Rating Fuels
Data on Hydrocarbons
X-Ray Diffraction Index
Standards for Students in Engineering
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Manual on Measuring and Sampling of Petroleum and Its Products
Procedures for Emission Spectrochemical Analysis
Report on Standard Samples for Spectrochemical Analysis

Symposiums

Plasticity and Creep of Metals
Effect of Sigma Phase on the High-Temperature Properties of Metals
Corrosion of Gas Turbine Materials at Elevated Temperatures
Radiography
Methods of Testing Soils Under Triaxial Loading
Identification and Classification of Soils
Ultrasonic Testing
Role of Nondestructive Testing in the Economics of Production
Application of Statistics
Use of Pozzolanic Materials in Mortars and Concretes
Rapid Methods for the Identification of Metals
Wood
Measuring Viscosity at High Rates of Shear
Turbine Oils

; is assembled. The new edition of
is book will be available in September.

anual on Quality Control of Materials:

This is a revision and amplification
the Manual on Presentation of Data
hich was published in 1940. The
ok is divided into three sections:
presentation of data, (2) presenting
is and minus limits of uncertainty
an observed average, and (3) control
art method of analysis of presentation
data. It is expected copies of this
ok will be available in October.

mposium on Statistics:

This symposium was presented at the
st Pacific Area National Meeting
t fall and covers the application of
tistical methods in industrial quality
ntrol. This book is discussed in
ater detail in this BULLETIN (see
ge 11). Copies are now available.

ta on Hydrocarbons:

Technical Committee H on Light
drocarbons of Committee D-2 on
troleum Products has made available
les of physical constants of light
matic hydrocarbons. The tables
divided into three parts and cover
following material: (1) naphthenes and aromatics, (2) paraffin hydrocarbons, and (3) mono-olefins, diolefins, and acetylenes. It is planned to keep the tables up to date through preparation of revisions from time to time as is found necessary. Copies will be available by October.

1950 Appendix to A.S.T.M. Manual of Engine Test Methods for Rating Fuels:

This appendix has been prepared by the Division of Combustion Characteristics, of A.S.T.M. Committee D-2 on Petroleum Products and Lubricants. It includes recent changes in the 1948 Manual of Engine Test Methods for Rating Fuels and also in the 1949 Appendix.

Manual on Measuring and Sampling of Petroleum and Its Products:

This manual is being prepared by Committee D-2 on Petroleum and will be the first volume of a projected set of oil measurement standards. It will contain a suitable introduction; three new Tentative Methods on Gaging, Sampling (including Volume Calculations and Corrections), and Temperature Measurement; also the Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (D 287 – 39) and the Tentative Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96 – 50 T). Copies will be available in October.

Symposium on Turbine Oils:

It is fitting, from time to time, for a group to review the progress it has made and to consider problems for the future. This was done by the authors of the four papers on turbine lubrication presented at the symposium which was held at the First Pacific Area National Meeting in San Francisco. The symposium should be of interest to all those connected with the lubrication of turbines and the development of test procedures for turbine lubricants. Copies of this symposium will be available this month. The titles of the papers are as follows:

Lubrication Problems and Requirements of Gas Turbine Equipment—F. C. Linn

Operating Experience and Problems Relative to Lubricating Systems of Steam Turbine Sets for Utilities—V. Estcourt

Specific Problems Pertaining to Lubrication of Industrial Turbines—A. S. Morrow

Lubrication of Marine Turbine Propulsion Equipment—F. S. Jones

"Filtering"

is photograph by
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S. Testing Co.,
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S.T.M. Photo-
raphic Exhibit.

NEW A.S.T.M. PUBLICATIONS

Latest Publications on Radiography, Statistics, Pozzolans, and Soils Testing Issued

In the past few weeks several important Society publications have made their appearance. Brief reviews of the new symposiums on radiography, pozzolans, and statistics, a review of a Report on the Electron Microstructure of Steel, descriptions of a 430-page collection of soils testing procedures, and on the combined Index of the 1949 Book of A.S.T.M. Standards appear below.

There is an extended descriptive article on page 6 which outlines present plans for the next few months.

Symposium on Use of Pozzolans in Mortars and Concretes

The Symposium on Use of Pozzolanic Materials in Mortars and Concretes presents a most complete picture of the present status of this important subject.

The papers and discussions which make up this symposium were presented at the First Pacific Area National Meeting in San Francisco, Calif., in 1949.

Starting with a definition and historical review of the early use of pozzolans and continuing with discussions of the use of pozzolans in mass concrete, the papers bring to light much interesting factual information hitherto only to be found in scattered sources. Experience with Kansas aggregates and pozzolanic additions is discussed. Also described is the effect of calcination on natural pozzolans and the effect of the use of diatomite treated with air-entraining agents upon the properties of concrete. There is a summary of methods for determining pozzolanic activity: strength, volume change, and sulfate resistance of mortars containing portland-pozzolan cements. In conclusion, two papers describe the use of pozzolans for counteracting the excessive concrete expansion resulting from a reaction between certain aggregates and the alkalies in cement.

The nine papers and pertinent discussions, from the table of contents, are listed below together with the various authors.

- Pozzolanic Materials and Their Use in Concrete—R. E. Davis
- Pozzolans Used in Mass Concrete—H. S. Meissner
- Experience with Kansas Aggregates and Pozzolanic Additions—C. H. Scholer
- Effect of Calcination of Natural Pozzolans—R. C. Mielenz, O. J. Glantz, and L. P. Witte
- Effect of the Use of Diatomite Treated with Air-Entraining Agents upon the Properties of Concrete—R. E. Davis and A. Klein
- Summary of Methods for Determining Pozzolanic Activity—W. T. Moran and J. L. Gilliland
- Strength, Volume Change and Sulfate Resistance of Mortars Containing Portland-Pozzolan Cements—R. E. Davis, W. C. Hanna, and E. H. Brown
- Studies of Some Method of Avoiding Expansion and Pattern Cracking Associated with the Alkali-Aggregate Reaction—W. C. Lerch
- Studies of Use of Pozzolans for Counteracting Excessive Concrete Expansion Resulting from Reaction Between Aggregates and Alkalies in Cement—T. E. Stanton

(*Discussions pertinent to the several papers are also included*)

The price for the 202-page "Symposium on Use of Pozzolanic Materials in Mortars and Concretes," *STP No. 99* is $2.50. To A.S.T.M. members the price is $1.85.

Procedures for Testing Soils

Now available is a compilation of standards and suggested methods prepared with the cooperation of many leading authorities; it covers specifically in its five parts the fields of exploration and sampling, physical characteristics and identification, physical and structural properties, special and construction control tests, and bearing tests in place and dynamic properties, respectively.

This extensive compilation of standard methods adopted by A.S.T.M., together with many suggested methods, for soil and soil mixtures resulted from the cooperation of many leading workers in this field. Sponsored by Committee D-18 on Soils for Engineering Purposes, the publication presents information that should be of interest to everyone concerned with soils and every type of structure or project influenced by the type of soil.

The 17 methods standardized by A.S.T.M. through the work of its Committee D-18 are given in their latest approved form, and in each of the five parts of the compilation are included suggested modifications of these, and numerous other suggested methods which have been used with some success by their authors and others.

The committee responsible devoted much time and effort in making the book of the most value possible. There is a general introduction and a separate explanatory foreword to each of the five major divisions covered.

Preparation of the suggested procedures in A.S.T.M. style involved a vast amount of editing and study which was carried out by a special subcommittee on procedure in soil testing.

Comprising 434 pages, heavy paper cloth cover, prices are: paper cover, 1 to 9 copies, $3.75 per copy; 10 to 49, $2.2[illegible] Prices to A.S.T.M. members are $2.[illegible] and $2.25, respectively. For cloth binding, add 65 cents to these prices.

1949 Book of Standards

In recent weeks the Society has been shipping the various volumes of the new six-part 1949 Book of A.S.T.M. Standards all over the world to Society members—to materials engineers and management personnel of both producer and consumer interests, governmental and testing agencies, and educational institutions. A description of the new Book of Standards appears on p. 3, this Bulletin.

Members' Order Blank for Special Publications

There was recently sent to each member a special order blank, with prospectuses of some of the newer publications, thus providing an opportunity for members to order these books. Those covered on the order blank included the following: High Additive Oils, Dynamic Stress Determinations, Pozzolanic Materials, Application of Statistics, Evaluation of Stainless Steels, Accelerated Durability Tests. Standards on: Soils, Cement, Mineral Aggregates, Glass, Rubber, Plastics. Report on: Electron Microstructures of Steel.

Descriptions of some of these books appear on this and following pages.

ymposium on Application of Statistics

THE recent publication of ree authoritative technical papers and e discussion comprising this sym- sium give further emphasis to the portance of the application of statis- s to quality control in modern testing. the past, through publication and de dissemination of its Manual on esentation of Data and the organiza- n of its Committee E-11 on Quality ntrol of Materials, A.S.T.M. has ade available important information d data in this very significant field of ality control and statistical analysis. e publishing of this Symposium on atistics held at the First A.S.T.M. cific Area National Meeting in San ancisco, October, 1949, is part of the ntinuing program.

"The importance of the application of atistics to quality control in modern sting has become so widely accepted at it needs no formal introduction," r. Wakeman, Testing Engineer, Los geles Harbor Dept., pointed out in a ort introduction to the symposium. e work of A.S.T.M. Committee E-11 Quality Control of Materials and the disputable mathematical sampling ocedures which assure that the quality the finished product will not fall below stated level were also mentioned by r. Wakeman. Mr. Wakeman, as airman of the Symposium Committee o noted that the three authors were ected not only for their facility for roducing the subject of application of atistics to those not too familiar with but also because they are so familiar th practical problems.

The three significant papers are as lows:

e Economic Relationship Between De- sign and Acceptance Specifications—Eu- gene L. Grant, Professor of Economics of Engineering, Stanford University

ecision and Accuracy of Test Methods— Grant Wernimont, Eastman Kodak Co.

e of Statistics to Determine Precision of Test Methods—W. J. Youden and J. M. Cameron, National Bureau of Standards

Symposium on Application of Sta- tics, *STP No. 103*, with heavy paper ver, 36 pages, is $1 per copy; to S.T.M. members 75 cents.

Extensive Report on Electron Microstructure of Steel—New Publication with 47 Micrographs of Widespread Interest

A REPORT on Electron Microstructure of Steel which should be of interest to all metallurgists and electron microscopists has recently been issued by the Society in the form of a 50-page pamphlet. Among other features it includes 47 specially prepared figures constituting electron micrographs of various steel constituents. This report, copies of which can be procured at the list price of $1.35—by A.S.T.M. members at $1—was developed through intensive work in the Subcommittee of Electron Microstructure of Steel which functions as part of Committee E-4 on Metallography.

Excerpts from the text of the report probably convey best what it covers...

"It was felt by interested metallurgists that, although the superior resolving power and magnification of the electron microscope had been utilized to very good advantage in many fields, progress in realizing its potentialities in ferrous metallurgy had been disappointly slow. Nevertheless, it was the consensus that the inherent advantages of this instrument should be of tremendous value in exploring the fine microstructures of steel, such as bainite, martensite, and tempered martensite, which are beyond the resolving power of the light microscope. It was believed, furthermore, that information of this kind would be extremely useful in advancing knowledge of the relationships between the morphology of these structures and the mechanical properties.... It was reasoned that a group of several laboratories, diligently applying a few of the most promising techniques to identical structures, should be able to determine what degree of consistency could be achieved among electron micrographs—first of all, on those microstructures which could be resolved with the light microscope, and therefore, could be compared directly, and finally, on those microstructures that are not resolvable by light microscopy.

"The research program, the results of which are the subject of this report, was formulated at the February 13, 1948, meeting. Essentially, this plan consisted of heat treating a series of pieces of a eutec-

"Bainite—Isothermally Transformed at 500° F."

First prize-winning electron micrograph, in the Seventh A.S.T.M. Photographic Exhibit, by W. L. Grube, General Motors Corp., Research Laboratories Div. This incidentally illustrates the type of electron micrograph appearing in the new report described above. Magnification: electronic 3,500×, original photograph 25,000×. Reduced to about three-fifth size in printing.

toid steel to specific microstructures, and dividing these pieces into specimens which were supplied to each cooperating laboratory for investigation by means of electron microscopy. Light micrographs of each of these structures were prepared at the United States Steel Research Lab. at a magnification of 2500 ×. These light micrographs, which are reproduced in this report, are believed to be representative of the best metallographic techniques currently available.

"The program for the electron microscope studies included some variations in metallographic polishing and etching practices, replica techniques, and photographic procedures. Both mechanical polishing and electropolishing were used to some extent, but mechanical polishing was used predominantly in obtaining the results reported here. The etching reagents employed in this work were picral, nital, and ferric chloride-hydrochloric acid. Three replica techniques were investigated, namely, formvar, parlodion, and polystyrene-silica. Most of the formvar and parlodion replicas were shadowcast either with chromium, platinum, or palladium to enhance the contrast. In general, the electron micrographs were made at an initial magnification of 5000 ×, and then were enlarged to a final magnification of 15,000 ×. In addition to these high magnification micrographs, electron micrographs of these structures were prepared at an initial magnification of 750 ×, and were enlarged to 2500 ×, in order to permit comparison with the light micrographs. For the most part, the enlarged prints were made directly from the photographic negatives, but in a few instances, reverse prints were made. Information pertaining to the electron microscope techniques and procedures is presented in detail in the Appendix to this report.

"From the large number of electron micrographs accumulated in this program, the series reproduced in this report have been selected as being most representative of the microstructures studied, and of the various techniques employed. The micrographs pertaining to these different microstructures are separately discussed in some detail."

As indicated, this complete report is now available to members at $1, the list price being $1.35. It is bound in heavy paper cover and printed on special paper to bring out the details of the micrographs.

The personnel of the subcommittee responsible for the report is published therein and includes as *Chairman*, G. E. Pellissier, Carnegie-Illinois Steel Corp., and as *Secretary*, D. M. Teague, Chrysler Corp. A. L. Ellis, International Harvester Co., had considerable to do with the early formation of the forerunner of this subcommittee.

New Index to Standards Sent to All Members and Book of Standards Purchasers

The Index to A.S.T.M. Standards as of December, 1949, has been published after some considerable delay, and a copy of this 250-page book in heavy paper cover is being forwarded to each A.S.T.M. member. In addition a copy of the book goes to everyone who has procured a complete set or any Parts of the 1949 Book of Standards.

This Index is a combined index to the six parts of the Book and is of considerable convenience in two major ways: first, in locating quickly, in the books where they are published, any of the standards; and, secondly, in determining whether the Society has issued standards of any particular material or subject.

The Index lists under appropriate headings the applicable specifications and tests together with designation, and gives a reference to the part of the Book where published.

For example, under "Brass" will be found listed the large number of standards applicable with appropriate subdivisions, these subdivisions also being arranged alphabetically. Under "Grain Size" are listed the several standards pertaining to this subject, etc.

A valuable part of the Index is a complete list of all standards and tentatives as of December, 1949, given in numeric sequence of the designations, together with a notation of the part of the Book where published. The delay in issuing the Index was due to several causes—printing problems in completing the Book of Standards itself, the great amount of editorial work needed because of the issuance of the book in six parts, and, too, because of the heavy editorial and technical load at Headquarters.

Members may procure extra copies of this Index on request without charge.

Members may also wish to procure a new List of Standards which should be issued about September, 1950. This will include the titles and designations of all standards effective on that date. This 60-page pamphlet is also available without charge.

Papers on Radiography

In an attempt to correlate late developments of radiography, the papers and discussions of a session on radiography at the 52nd Annual Meeting of the American Society for Testing Materials held in Atlantic City, N. J., in 1949 have now been published. The radiography session was sponsored by Committee E-7 on Non-Destructive Testing.

Leslie W. Ball, in his introduction to the symposium says.... "There has been a fascinating surge forward in two aspects of this still young and vital technology. These rapidly developing aspects are in the engineering of radically new equipment and in the skilled exploitation of nondestructive testing in the management of engineering and material-processing development projects."

In this volume, three papers deal with progress in the development and application of electrostatic and betatron-type X-ray generators operating at potentials above the familiar one million volt range.

One of the papers deals with the development and application of an X-ray machine for studying material and engineering parts in motion. In this, a single picture is obtained at a speed sufficient to stop even explosive rates of motion. Other papers deal with progress in technique and with those aspects of industrial radiography with which Committee E-7 has the most immediate concern, namely, the specification of the radiography procedure by technique calculators and penetrameters and the establishment of a general framework for standards for the purchase of material and engineering parts on the basis of X-ray inspection. Specifically, the new "Papers on Radiography" contains the following:

Recent Progress in Flash Radiography —J. C. Clark

10 Mev X-ray Technique—D. T. O'Connor, E. L. Criscuolo, and A. L. Pace.

Radiography and Autoradiography by Photoelectrons—D. T. O'Connor and W. R. Maddy

Mobilizing the Van de Graaff Generator for Precision Radiography—E. A. Burrill

A Universal Exposure Calculator for Radium Radiography and Its Application to Current Radiographic Films and Techniques—N. A. Kahn, E. A. Imbembo, and J. Bland

A Discussion of Radiographic Sensitivity—C. H. Hastings

A Revised Procedure for Establishing Radiographic Standards—L. W. Ball

An Investigation of Radiography in the Range from 0.5 to 2.5 Million Volts—W. W. Buechner, R. J. Van de Graaff, H. Feshbach, E. A. Burrill, A. Sperduto, and L. R. McIntosh

(*Discussions pertinent to the several papers are also included*)

This 95-page "Papers on Radiography," *STP No. 96*, bound in paper cover, can be obtained for $1.75. To A.S.T.M. members, price is $1.35.

A.S.T.M. Activity in the Field of Building Codes

THOSE interested in the tremendous building construction program which has set new records in volume during the past four years have also been aware of the increased efforts to bring antiquated building codes up to date or to write new ones. In this modernization program there has been a trend toward requirements based on performance established under standard tests as compared with detailed and exact specifications of certain materials. Both have certain advantages and both types are probably needed in a building code. The performance type of requirement, however, has the particular advantage in that it allows the use of new materials as soon as they have demonstrated their value under test without the necessity of amending the code.

There has been much activity on the part of municipalities and cities, both small and large, in the writing of new—or revision of old—building regulations. But more significant has been the attempts to standardize building codes in certain states as well as to develop national or uniform codes. The movement toward the adoption of state codes is a progressive one toward the eventual recognition and use of national standards.

The Society has played an important part in the writing of building codes throughout the years. As a necessary part of every code there must be a means of authority provided whereby a material or a construction can be measured to establish its ability to meet the requirement desired. A.S.T.M. methods of tests and specifications have been providing standard and nationally recognized means of doing this.

Regular review of existing standards by the technical committees helps to keep them up to date to meet modern building requirements. Development of new testing methods and specifications help to fill in the gaps when additional quality requirements are needed.

In the 1949 Book of A.S.T.M. Standards there will be found approximately 1250 tentatives and standards which apply directly to materials used in building construction. Of these, over 100 are specifications; 140 are methods of tests; the rest are definitions of terms. There are many more which have a more indirect usage. In a recent staff survey of the nationally developed building codes of the United States and Canada, it was found that 86 A.S.T.M. specifications, 42 test methods, and 5 lists of definitions are referred to. This included the codes developed by the Building Officials Conference of America, Pacific Coast Building Officials Conference, Southern Building Code Congress, National Board of Fire Underwriters, and the National Housing Administration and National Research Council (jointly) of Canada.

In keeping with the trend toward performance requirements in building codes there have been developed A.S.T.M. standard methods of testing which enable building authorities to secure the necessary data for establishing the acceptance of materials and of constructions. The Standard Method of Fire Tests of Building Construction and Materials (E 119) is nationally recognized as a means of rating the fire resistance of structural elements of a building based on a time-temperature performance. This standard has been revised this year to include a tentative test method to provide an alternate method of conducting fire tests of structural floor beams and girders without application of load, the limits of fire endurance being defined by the temperatures of the steel at critical locations. Another new tentative test method is that for determining the fire hazard classification of building materials, which is urgently needed by manufacturers and building code authorities.

The Tentative Methods of Conducting Strength Tests of Panels for Building Construction (E 72T) provides another performance test method whereby engineering data can be obtained on various construction elements and structural details, such as walls, partitions, floors and roofs, regardless of the materials involved, which is of value to designers, builders and building officials. A companion to this is the Tentative Methods of Testing Truss Assemblies (E 73T).

The accomplishments of one of the newer technical committees of the Society, Committee C-19 on Structural Sandwich Constructions, will add to the list of A.S.T.M. standards of the performance type. These methods will be useful in obtaining data on materials, or combination of materials, which are new in the building construction field.

The Society has endeavored to cooperate in every way possible with all agencies and organizations interested in the writing of building codes and especially in the unification of these codes. One of the most difficult problems in the building code field is to keep authorities informed of the latest form or revision of the A.S.T.M. standards and for them to provide means of adapting the use of their codes to include the latest standards. Where suitable legislation has been enacted, the references can be made in a code to the standard of latest issue, thus keeping the code up to date in this respect. In many cases free copies of the latest revisions are sent to the responsible persons. It is clear, of course, that membership in the Society provides the best contact whereby a building code authority would be kept informed. Letters soliciting membership have been sent to chiefs of building inspection departments and building code committees.

Representatives of the Society participate in other technical groups such as the Building Code and Construction Standards Correlating Committee of the American Standards Association. Under the supervision of this correlating committee are several sectional committees of A.S.A. dealing with specific materials and constructions and on these A.S.T.M. is also represented.

A somewhat unusual procedure during the past year was the granting of permission to publish A.S.T.M. standards, or excerpts thereof, under the designation of another organization. Volume II of the Uniform Building Code of The Pacific Coast Building Officials Conference contains all standards referred to in the first volume under U.B.C. designation and giving proper recognition to the originating authority.

The right to reprint A.S.T.M. standards has been granted to other organizations especially to technical groups, thus preventing much duplication of effort in development of standards and recognizing the universal acceptance and adaptability of A.S.T.M. standards.

The Society stands ready to continue its cooperative policy with all building code authorities.

Annual Water Conference Program of Widespread Interest

THE PROGRAM of technical papers for the Eleventh Annual Water Conference, sponsored by the Engineers' Society of Western Pennsylvania, will be of widespread interest, specifically to those who are concerned with this important material. The 1950 sessions are scheduled for the Hotel William Penn, Pittsburgh, October 16–18, inclusive. A number of A.S.T.M. members are active in the conference—M. D. Baker, Max Hecht, F. R. Owens, and S. F. Whirl serving on the Advisory Committee. Mr. Hecht, Chairman of A.S.T.M. Committee D-19 on Industrial Water, will be the presiding Chairman at the Thursday afternoon session. More details, including a list of the papers, can be procured by writing the E.S.W.P., Hotel William Penn, Pittsburgh; W. M. Porter is the Secretary.

Personnel of Board of Directors and Committees

THE By-laws of the Society provide that the Board of Directors shall appoint an Executive Committee which will exercise for the Board certain delegated authorities, and provision is made also for the appointment of other committees of the Board covering such phases of the work as membership, inter-society relations, etc. The personnel of the new Executive Committee functioning during 1950–1951 and the six other subcommittees which have been appointed is given below. Preceding this information there is published a complete list of the personnel of the Board of Directors with the titles and addresses of the Directors.

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President Markwardt is an *ex-officio* member of all Board committees.

At the 1950 Annual Meeting of the Society, T. L. Condron was awarded a certificate honoring his 50 years of membership with, and service to, A.S.T.M. He has written an interesting acknowledgment which appears below.—ED.

An Acknowledgment to the American Society for Testing Materials by Theodore L. Condron, June 29, 1950

I AM greatly honored that the Board of Directors of the American Society for Testing Materials has conferred upon me this special Certificate in recognition of the completion of 50 years of my personal membership in this remarkably useful and efficient engineering Society, now known throughout the civilized world as the A.S.T.M.

When Robert Job and I were elected members, in 1900, of the American Section of the International Association for Testing Materials, with a membership of 160, we could not have conceived that, within our lifetime, this small group of 160 members of all classes would expand to more than 6000 members, and that the number of Standing Committees would be expanded from less than five to more than 70, with more than 4000 members serving on these important committees.

I feel a reasonable pride in the fact that I, apparently, was appointed a member of and attended several meetings of the original Committee No. 1 of the American Section of the International Association for Testing Materials, which committee collected, tabulated, and published in Volume I of the *Proceedings* of the American Section of the International Association for Testing Materials [the predecessor of the American Society for Testing Materials], nine lengthy tabulations called "Synopses of Specifications." The longest synopsis was the one for "Rolled Steel for Bridges and Buildings," which covered the specified physical and chemical requirements of more than 60 railroad companies, manufacturers, and consulting engineers

throughout the United States and Canada. It was impossible for the ordinary mind to grasp the meaning and significance of such a lengthy tabulation.

Committee No. 1 did, however, study this particular synopsis and its members were aided in doing so by a pictorial diagram which was part of my paper, "Specifications for Materials and Workmanship for Steel Structures," which was presented by me in 1901 at a meeting of the Western Society of Engineers and which was printed in their *Journal* (1903). The diagram showed the variations in the physical and chemical requirements of a large number of specifications, making a comparison with the specification prepared by the American Section of the International Association of Testing Materials. The chart had been widely circulated by me to engineers and manufacturers in the United States and Canada.

This paper was discussed orally and by letters from a number of members of the W.S.E. including bridge engineers of railroads centering in Chicago and the representatives of steel mills and fabricating shops. In my closure to this discussion, I stated, "since my paper's presentation in 1901, the Committee of the American Railway Engineering and Maintenance of Way Association, of which I was and am a member, reported at the March, 1901, meeting of the Association, a 'Specification for Materials and Workmanship for Steel Structures', which had been adopted by the Association and had become the Standard Specification to be recommended by that Association." This specification differed somewhat from my individual recommendations but I willingly approved.

At a meeting of the Association of American Steel Manufacturers on February 6, 1903, the practical value of a uniform Specifications for Rolled Steel for Structural Purposes was discussed and the suggestion advanced by the Committee of the American Railway Engineering and Maintenance of Way Association on Iron and Steel Structures, for the adoption of one grade of steel for all structural purposes (except rivets) was approved and adopted. This was so reported to the A.S.T.M. in June, 1903, by Albert Ladd Colby, in presenting the Specification of the Association of Steel Manufacturers.

Thus, the efforts of the American Section of the International Association for Testing Materials started in 1901 were finally crystallized in 1903 into the definite adoption of a Uniform Specification for Rolled Steel for Structural Purposes.

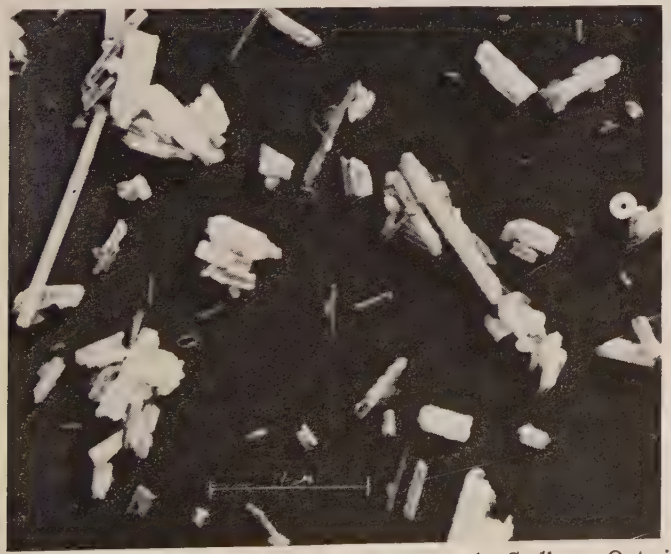
The National Fuel Exchange Groups

THE three National Fuel Exchange Groups for motor gasoline, aviation gasoline, and diesel fuel were formed a number of years ago by companies and institutions interested in maintaining standards for knock ratings of these fuels by "round-robin" testing of fuel samples and exchanging test results. Until about three years ago the activities of the Exchange Groups, consisting principally in arranging for procurement and distribution of monthly exchange samples and the analysis and dissemination of the test results, were managed by the Cooperative Research Council, a corporation formed by the Society of Automotive Engineers and the American Petroleum Institute to carry on research on automotive fuels and lubricants and their applications to engines. Since the work of the Exchange Groups is primarily standardization and not research, and since A.S.T.M. in the meantime had developed the now well-known Engine Test Methods for Rating Fuels, CRC asked A.S.T.M. late in 1947 if it would undertake the responsibility of managing the Exchange Group activities. About the same time our Committee D-2 on Petroleum Products and Lubricants had established its Research Division I on Combustion Characteristics of Engine Fuels (DCC), so that this committee and DCC were prepared to undertake this responsibility. The Society accepted the assignment and the work was turned over to Committee D-2 and DCC in December, 1947, with A.S.T.M Headquarters handling certain clerical and financial details on a reimbursable basis.

The National Bureau of Standards had for a number of years handled clerical and statistical work involved in the operation of the project and agreed to continue this under A.S.T.M. sponsorship with suitable reimbursement. Recently, in view of various considerations and by mutual agreement, NBS has discontinued its part in the project, and by agreement effective July 1, 1950, the U. S. Bureau of Mines is carrying out this work for the Society. Effective at the same time, D. B. Brooks, who for many years was leader of these groups, has retired from that post and has been succeeded by R. M. Gooding, a member of the Bureau of Mines staff. Mr. Gooding may be addressed as Leader, A.S.T.M. - DCC National Fuel Exchange Group, Bureau of Mines, Washington 25, D. C. Mrs. R. B. Cleaton, who was associated with this work for many years at the Bureau of Standards, is continuing with it at the new location.

Mr. Brooks continues as chairman of D-2's Research Division on Combustion Characteristics and may be addressed in care of the Research and Development Board, National Military Establishment, Pentagon, Washington 25, D. C.

There are about 35 members of the combined Fuel Exchange Groups. The project is supported by group membership dues and by fees for semiannual tests open to nonmembers. The value of the project to the petroleum, automotive, and other industries and to the Armed Services, particularly in time of emergency, in maintaining a high standard of accuracy and precision in the knock rating of fuels, can hardly be overestimated.



"Electron Micrograph of Serpentine from Espanola, Sudbury, Ontario"

A first prize-winning electron micrograph, in the Seventh A.S.T.M. Photographic Exhibit, by F. G. Rowe, D. W. Davis, and Prof. P. F. Kerr, Columbia University, and T. G. Rochow, American Cyanamid Co. Original 10,200 ×; Final 76,500 ×.

ASTM Bulletin

SEPTEMBER 1950

NO. 168

NINETEEN-SIXTEEN
RACE STREET
PHILADELPHIA 3, PENNA.

IN APPRECIATION

THE article on standardization activities appearing in this BULLETIN, as well as the Annual Meeting article covering committee activities appearing in the July issue, serve to call attention to the accomplishments of these committees and the tremendous amount of work being carried on by them. It is easy enough to imagine the great number of man-hours that go into this work such as in round-robin tests and various other aspects of the committees' activities. The many valuable accomplishments have taken commensurate effort.

But what is perhaps frequently lost sight of is the accompanying effort that goes into the guiding of the actual committee work, through the many meetings of advisory or steering committees, and more particularly through the thought devoted to the work by the committee officers. All of these services are voluntary and much of the time spent is "out of hours." This is a year for the election of committee officers and with this in mind there is given on page 38 a listing of the present officers. But wherever an asterisk appears, indicating the election of a new officer, some other officer is stepping aside, frequently after many years of hard work and unselfish service. A welcome is extended to all individuals who are now taking up these tasks, and a sincere expression of appreciation is offered to those officers who are retiring or continuing to serve, for their many generous contributions of time and effort in the past.

1951 and 1952 Meetings of A.S.T.M.

1951

Spring Meeting and Committee Week
Cincinnati, Ohio
March 5 to 9, inclusive

Annual Meeting
Atlantic City, N. J.
June 18 to 22, inclusive

1952

Spring Meeting and Committee Week
Cleveland, Ohio
March 3 to 7, inclusive
(probably)

Annual Meeting
New York, N. Y.
June 23 to 27, inclusive

The biennial Apparatus and Photographic Exhibits will be held in conjunction with this Annual Meeting.

Schedule of A.S.T.M. Meetings

DATE	GROUP	PLACE
September 11–12	Board of Directors	Philadelphia, Pa.
September 13–15	Joint TAPPI-A.S.T.M. Committee on Petroleum Wax	Rochester, N. Y.
September 14	Committee C-8 on Refractories	State College, Pa.
September 14–15	Committee D-21 on Wax Polishes and Related Material	Washington, D. C.
September 24	Committee C-21 on Whitewares	Bedford Springs, Pa.
September 26	Administrative Committee on Standards	Philadelphia, Pa.
September 27–28	Committee B-5 on Copper and Copper Alloys	New York, N. Y.
October 6	Committee C-14 on Glass and Glass Products	Toledo, Ohio
October 8–11	Committee D-2 on Petroleum Products and Lubricants	Detroit, Mich.
October 9–10	Committee C-1 on Cement Committee C-9 on Concrete and Concrete Aggregates	Skokie, Ill.
October 11–12 (Tentative)	Committee D-4 on Road and Paving Materials	Evanston, Ill.
October 12–13	Committee C-22 on Porcelain Enamels	Mansfield, Ohio
October 12–13	Committee D-10 on Shipping Containers	Philadelphia, Pa.
October 13	Ohio Valley District	Columbus, Ohio
October 18–20	Committee D-13 on Textile Materials	New York, N. Y.
October 19–20 (Tentative)	Committee D-14 on Adhesives	Boston, Mass.
October 23–25	Committee C-16 on Thermal Insulating Materials	Asbury Park, N. J.
October 26–27	Committee C-19 on Structural Sandwich Construction	Madison, Wis.
November 14–15	Committee D-20 on Plastics	Cincinnati, Ohio
November 15–17	Committee D-9 on Electrical Insulating Materials	Cincinnati, Ohio
November	Committee C-20 on Acoustical Materials	Boston, Mass.
January 15–16, 1951	Board of Directors	Philadelphia, Pa.
March 5–9	SPRING MEETING AND COMMITTEE WEEK	Cincinnati, Ohio
June 18–22	54TH ANNUAL MEETING	Atlantic City, N. J.

Should Standards Approval System Be Changed?

EDITORIAL NOTE.—In the last issue of the Bulletin, the article "Should Method of Acting on Committee Reports and Standards Be Changed?" was reprinted together with two letters of comment, from W. J. McCoy, Lehigh Portland Cement Co., Allentown, Pa., and Francis X. Mardulier, Dewey & Almy Chemical Co., Cambridge, Mass. K. G. Mackenzie, The Texas Company, New York, N. Y., has prepared a statement endorsed by Committee D-2 on Petroleum Products and Lubricants which appears below as further word on this important question. Messrs. Jonathan Jones and R. C. Adams have also written, their letters appearing below.

THE American Society for Testing Materials is the leading standardization body in the world.

Its indubitable position has been secured by the excellence of its standards, and this excellence, in turn, so far as petroleum products are concerned, has been due to the wholehearted, unselfish contributions of producers and consumers of petroleum products who are members of Committee D-2 on Petroleum Products and Lubricants and the various subdivisions thereof.

This wholehearted support contributed by both producers and consumers has been due mainly, at least, to the democratic machinery in A.S.T.M. which is followed in the adoption of standards. Some other organizations have attempted work of somewhat similar scope but with the difference that standards are arrived at from "star chamber" proceedings with the producing interest frequently excluded.

Present A.S.T.M. machinery provides that in adoption of standards, every member of a committee and, indeed, any visitor, has his day in court. If a member of a committee is not satisfied with a decision of a committee in the matter of a standard, he can present his case before the members of the Society in Annual Meeting assembled. Any other individual, a member of the Society or otherwise, is afforded a similar opportunity. The final decision is in the hands of the members of the Society.

It is true that to overcome criticism levied by some, that A.S.T.M. procedure was too cumbersome, a short cut has been provided in the Administrative Committee on Standards. The authority of this committee is limited to tentatives and to withdrawal of Standards, and so far this short cut has worked well. In the case of a member of a technical committee dissenting, this member is permitted to appear before the Administrative Committee on Standards and present his case. On the other hand, the authority of the Administrative Committee on Standards is limited to *ad interim* approvals between Annual Meetings, and each committee has the option of presenting its recommendations either to the Administrative Committee on Standards or to the Society in Annual Meeting assembled, and if, by chance, the Administrative Committee on Standards should refuse to accept the recommendation of a Technical Committee, this results only in delay, since the committee can, at the following Annual Meeting, present its recommendations to the members of the Society.

A proposal is now being considered by the Board of Directors of A.S.T.M. to eliminate approval both of standard and tentatives by the Society in Annual Meeting assembled, and to substitute therefor, what are called Review Panels, the membership of which will be determined by the Board of Directors of A.S.T.M. The adoption of this proposal would place the fate of Committee D-2 and all of its work in the hands of a small group which could not have the necessary knowledge to pass on the technical aspects which might be involved without being drawn from the membership of Committee D-2, and if drawn from Committee D-2 would have the effect of the selection by the Board of Directors of certain members of Committee D-2 who would be given the veto power over the work of the Committee.

The proponents of this more or less bureaucratic plan point to the fact that approvals by the members of the Society in Annual Meeting assembled have, in certain cases, been more or less of a gesture, since no discussions have taken place nor have negative votes been registered. This simply proves that more and more in the work of the technical committees of the Society, the committees themselves within their organization secured "a satisfactory consensus" (see regulations governing Technical Committees Section 15 (*e*)). The present machinery, as stated above, now provides a final and fair hearing by the Society of objections anyone may have. Committee D-2 feels that the change from the present to the proposed procedure will imperil those democratic principles that have contributed to A.S.T.M.'s healthy growth, wide acceptance of its Standards, and enthusiastic support of both consumers and producers—by substituting therefor an autocratic bureaucracy.

K. G. MACKENZIE

Dear Sir:

To the writer, both the present procedure and the proposed procedure for adoption of standards after their adoption by the main Technical Committees appear to be unrealistic, unnecessarily time-consuming, and an echo of the times when this was a much smaller and simpler Society.

If one looks realistically at the Society of today, he must recognize that the real decisions about standards are made in the main Technical Committees, A-1, A-2, B-1, D-1, etc., that the proper forum for their final perfection is in the meetings of those technical committees, that final approval by the Society at large can be only perfunctory, and that therefore this final approval should be as simple and effortless as possible. It is no denial of "Democracy" to say that a decision arrived at in a meeting of Committee A-1 in which are gathered all those who are interested in steel, is not going to be improved by further discussion at a larger meeting attended by some of those who are interested in steel, some who are interested in cement, some who are interested in rubber, and some who are interested in paint.

The writer would therefore suggest that the submission of standards to the main Annual Meeting for discussion and vote be abandoned in favor of a mere statement to the meeting that such and such standards have been forwarded for approval from the technical committees and will be submitted to letter ballot.

Naturally, in that case, every care should be taken to see that the meetings of the main Technical Committees, A-1, etc., afford sufficient time and sufficient advance notice, for all interested parties, whether members of the committee or not, to debate the recommendations of the subcommittees before action is taken by the main technical committee. The details of such precautions should not be too difficult to work out, if the foregoing principle should meet with favor. There probably would be involved, a predistribution of the agenda for subcommittee meetings and the corresponding main technical committee meetings, sufficiently in advance of the meetings, to a much wider group than the personnel of those subcommittees and committees; to the end that the debates in the subcommittee meetings and then in the main technical committee meetings should be open to all, and as nearly as possible conclusive.

Yours very truly,
(Signed) JONATHAN JONES

Dear Sir:

The proposed Review Panels would extend to Standards the function now performed with respect to Tentatives by the Administrative Committee on Standards. This would be highly desirable if in doing so two evils can be avoided. The first is the silencing of a Society member who has a legitimate objection to a proposed committee action. The second is the frustration or distortion of carefully considered committee efforts by trivial or unjustified objections.

It is conceivable that a technically unsound proposal could pass through the gauntlet of committee discussions, voice votes, and letter ballots to be recommended for adoption by the Society. Or a committee, considering only the technical principles involved, might overlook or disregard social or legal implications of their proposal. In these or similar cases it is the duty of any member of the Society to voice his objection to the proposal. Similarly, it is the duty of the Society to insure that such objections will be heard and considered.

The personnel of the technical committees comprise the best qualified in-

dividuals in their respective fields which the Society membership can provide. The considered recommendations of such groups should not be lightly set aside. No Review Panel, however constituted, would be better qualified to judge technical proposals than the technical committee itself. Even if the Panel included members from the committee concerned, these few individuals should not be permitted to modify the decisions of larger and more representative technical committee. No authority for change in committee proposals should be interposed between the technical committees and the Society.

I believe this course between Scylla and Charybdis can be steered by making the Review Panel a jury, not a judge. The Review Panel would receive a technical committee report at an open hearing, scheduled in advance in the Annual Meeting program so that any interested person could appear and speak. After hearing the report, and any objections, the Panel could take only one of two actions. The first would be to approve the report and its proposals, subject to letter ballot of the Society; the second would be to return the report, or any designated portions of it, to the technical committee for reconsideration.

The Review Panel, being a jury, should act only unanimously. We all know that in Society balloting one cogent *No* has more weight than a bale of routine *Yeses*. If the objectors to a committee proposal can convince only one member of the Panel (presumably men of judgment and sincerity) that their objections are valid, then the proposal should be returned to the Committee for reconsideration. We can expect that virtually all committee reports and proposals will be approved by the Panel. However, in the rare case of a legitimate objection, the members, the committees, and the Society will be protected against arbitrary and unqualified changes. There thus will be no suspicion of star-chamber proceedings and the democratic processes of the Society will be preserved.

Very truly yours,

(Signed) R. C. Adams

U. S. Naval Experiment Station, Annapolis, Md.

L. F. Warrick, U. S. Public Health Service, and H. G. Dyktor, Cleveland Air Pollution Control to Speak at A.S.T.M. Columbus Meeting, October 13

Two outstanding authorities on atmospheric pollution and on water pollution will be the chief speakers at the meeting in Columbus on October 13 sponsored by the A.S.T.M. Ohio Valley District. Lewis F. Warrick, Chief, Technical Service Branch, Division of Water Pollution, U. S. Public Health Service, will discuss important current aspects of water pollution and control; Herbert G. Dyktor, Commissioner, Division of Air Pollution Control, Cleveland, Ohio, will discuss atmospheric pollution.

This technical meeting will be preceded by an afternoon tour of Battelle Memorial Institute starting at three o'clock, and this in turn is to be followed by a dinner at Ohio State University starting at six o'clock. The technical program follows immediately after the dinner.

The Program Committee acting for the District is headed by C. E. MacQuigg, Dean of the College of Engineering, Ohio State University, with local members cooperating and with the advice and counsel of Dr. H. P. Munger of Battelle Memorial Institute.

In electing to highlight programs on atmospheric and stream pollution, the Committee members were cognizant of the intense interest and important aspects of this subject in the Ohio area and deemed themselves fortunate in obtaining topnotch speakers such as Messrs. Dyktor and Warrick.

Because it is expected there will be considerable discussion and numerous queries, the Committee thought it appropriate to have a special panel of leading authorities for each branch. The personnel of the respective panels is given below. It will be noted that the Committee has included in the panels representatives of industry, the public, officials, and others.

Further details of this most interesting meeting, including further advice on the Battelle tour and the dinner (reservations will be solicited), will be sent to each member and committee member in the Ohio Valley District; and notices will also go to the members of a number of other interested local sections and chapters.

This is the second meeting to be sponsored by the District, really the first since its formal organization, and the officers, including Chairman J. C. Harris, Monsanto Chemical Co., Dayton, Ohio, and Secretary J. C. Pitzer, The Formica Co., Cincinnati, Ohio, are desirous that there be a good turnout of A.S.T.M. men. It is expected that officers of the Society and representatives of the Headquarters Staff will be present, and the meeting will afford an excellent opportunity for meeting others in A.S.T.M.

It should be noted that this is the Friday of a weekend when there will not be a football game at Ohio State. The University team is playing away. Nevertheless, those who plan to stay overnight are urged to make their hotel reservations promptly.

Atmospheric Pollution

Speaker—H. G. Dyktor, Commissioner, Division Air Pollution Control, Cleveland, Ohio.

Panel —H. C. Ballman, City Official, Columbus, Ohio.

H. P. Munger, Battelle Memorial Institute, Columbus, Ohio.

C. A. Gosline, Consultant, Trade Wastes, E. I. du Pont de Nemours and Co., Inc., Wilmington, Del.

H. B. Lammers, Coal Producers Commission for Smoke Abatement, Cincinnati, Ohio.

Water Pollution

Speaker—L. F. Warrick, Division of Water Pollution, Washington, D. C.

Panel —L. Drew Betz, General Manager, W. H. & L. D. Betz, Philadelphia, Pa.

F. H. Waring, State Department of Health, Columbus, Ohio.

C. V. Youngquist, Chief, State Water Division, Columbus, Ohio.

H. D. Lyons, Carbide & Carbon Chemical Corporation, South Charleston, S. C.

T. F. Reed, United States Steel Co., Pittsburgh, Pa.

C. A. Snavely, Battelle Memorial Institute, Columbus, Ohio.

Wood Study Kit

To those interested in the study of commercial species of wood as well as wood products, a compact wood study kit is being made available for use of technical men, teachers, students, libraries, Scout and other such organizations. This consists of 54 specimens of important commercial species of wood and wood products neatly packed in a small wood box together with a knife, a 10-power hand lens, and an 84-page illustrated manual. The cost of this kit is $8.50 and can be obtained from the Timber Engineering Co., 1319 18th St., N. W., Washington 6, D. C.

Technical Committees Push Standardization Projects

Many Activities on Numerous Materials

In the September issue of the 1949 ASTM Bulletin, and formerly in the August issue of Bulletins of recent years, there has been given a "round-up" of important standardization activities under way in the various technical committees. Again this year, the material which follows is a "look-ahead" and should provide some conception of the tasks set up and in progress. The information is based in part on current reports of the technical committees and also in large measure on committee work programs sent in to Headquarters by the various officers. Much of this information is of interest to the membership broadly, and it is also a great help to the Administrative Committee on Standards and the Staff.

Arrangement of Material

The material which follows is arranged in general in the order of the designations of the technical committees; for instance, the "A" and "B" groups, ferrous and non-ferrous, respectively, appearing first, followed by the "C," "D," and "E" groups.

Ferrous and Non-Ferrous Metals—"A" and "B" Committees (see also "E" Groups)

A-1 Steel

Many of the product subcommittees functioning under Committee A-1 on Steel have important standardization projects under way. Some of the products covered include structural steel, concrete reinforcement steel, forgings, castings, pipe and tubing, bars, valves, flanges, fittings, etc., for elevated and low-temperature service.

Some of the matters noted below will probably be referred to the A.S.T.M. Administrative Committee on Standards during the fall or early winter for approval. Others will not be completed until next year. It is suggested that those reading this material refer to the July ASTM Bulletin where there was considerable information on the past year's accomplishments of the committee.

For some time the Ship Steel Specifications A 131 have been obsolete in some respects and they are soon to be brought up to date. Three grades of steel based upon thicknesses are to be covered, with the various requirements very close to present shipping codes. The requirements for Nickel Steel, A 8, which is the only structural specification not included in the present structural grouping involving the use of the General Requirements Standard A 6 are to be modified so that the general document can apply to it.

Certain details of the important revisions in the four reinforcing bar specifications covering new billet material, rail steel, axle steel bars, and the Deformation Requirements A 305, were noted in the July Bulletin, p. 28. The recommendations, including the reversion of these specifications to the status of tentative, will be referred to Committee A-1 on Steel for letter ballot in the near future and then to the Society's Administrative Committee on Standards for approval. It is the hope of Subcommittee V that these specifications can be issued in their latest form during the early fall.

One of the very perplexing problems in the work on steel forgings involves the development of a series of photomacrographs which would show various defects in steel forgings to be used in connection with Tentative Methods A 317. Committee members are devoting considerable time to this, and excellent progress has been made. Further study is continuing on changes in the Carbon- and Alloy-Steel Blooms and Billets Specifications, A 273 and A 274. Among the subjects on which there is some divergence of opinion is that of check analysis. A new specification for alloy steel seamless drum forgings is being drafted and also requirements for forged cylinders.

Increasing the maximum silicon content of all steel casting grades in the widely used Specification A 27 is being recommended, and changing the yield requirement of the 120-100 grade in Specification A 148 from its present figure of 100,000 to 95,000 psi. also is in progress. Further study is being given to a draft of a standard for steam turbine castings. There are certain points in the current draft on which agreement has not been reached.

Work is progressing in Subcommittee IX on requirements for tubes for low-temperature applications. The Alloy-Steel Boiler Tube Standard A 213 is to be reverted to tentative with a new type 309 steel added and type 310 modified. In Grade T 16 of this standard the important problem of titanium content will be considered further.

The work on plates for pressure vessels includes a renewed study of a proposed $8\frac{1}{2}$ per cent nickel steel. Approaching completion is a 4 to 6 per cent chromium, $\frac{1}{2}$ per cent molybdenum plate specification and approval by letter ballot in the main committee will precede reference to A.S.T.M. in the fall of the 1 per cent chromium, $\frac{1}{2}$ per cent molybdenum grade, which would be added to Specification A 301. Study also continues on another composition involving $2\frac{1}{4}$ per cent chromium, 1 per cent molybdenum.

In cooperation with the Subcommittee on Bar Steels the group concerned with materials for pressure vessels is studying the standard on Rivet Steel and Rivets A 31, to determine whether changes are desirable. A complete redrafting of the alloy steel bar specification based on hardenability requirements, A 304, is proceeding, and virtual approval in the subcommittee has been reached on a new standard for cold-finished alloy steel bars. Several revisions in other bar specifications will be referred to the Society, including those covering medium-carbon steel bars, A 306, hot-rolled alloy material, A 322, and heat-treated alloy bars, A 286. An extensive table and article on these series of A.S.T.M. steel bar specifications was published in the May, 1950, Bulletin.

There are several active sections in Subcommittee XXII which cover valves, flanges, and fittings for high- and low-temperature service. These relate to castings, welding fittings, bolting, pipe, and related materials. Among the active projects are the following: new specification for castings for low-temperature service; revisions of the welding fittings specifications, A 234, with some changes to be approved in the near future and others next year; the addition of hardness requirements in certain of the bolting standards to assure uniformity; and a better system of identifying bars in the bolting specification, A 193. Also being studied is a proposed standard for pipe for low-temperature service with three ferritic grades, and requirements for fusion-welded alloy pipe in large sizes.

A-5 Corrosion

Committee A-5 is studying a revision of the method for determining the weight of zinc coatings in which a 1:1 hydrochloric acid would be used instead of concentrated acid (A 90). Consideration is being given to the use of circular coupons and rectangular coupons in A 90, as well as the presently used square test coupons. The effect of various zinc coatings (hot dipped, electrodeposited, heat treated, etc.) in copper sulfate solutions is being investigated and the Hull-Strausser type

dropping test is being studied. Various types of gages for measuring thickness of coatings applied to a ferrous base are being investigated.

The Subcommittee on Sheet Specifications is studying the need for revising the coating bend test in Specification A 93 to include heavier gages in all weights of coatings. It is also looking into the need for separate specifications for roofing sheets and as a first step, a draft of such a proposed specification has been prepared which covers 1.25-oz. coatings. This will be expanded to include other recognized weights of coatings.

Work is in progress on the preparation of specifications for chain-link fence galvanized before weaving. After completion of this specification, the Standard Specification for Zinc-Coated Iron or Steel Chain-Link Fence Fabric Galvanized After Weaving (A 117) will be reviewed to determine the need for increasing the weight-of-coating requirement. It has been claimed that angles and channels 1 in. or 1½ in. in size cannot take the weight of coating as specified in Specification A 123 for structural steel shapes and also that Specification A 153 for hardware is not applicable. A study of this problem is currently being made. Specification A 153 (zinc coating on iron and steel hardware) is being studied as to the need for including low-allow high-strength steel, galvanized after fabrication.

The exposure programs of black and galvanized sheets and wire and wire products are continuing.

A-6 Magnetic Properties

Committee A-6 on Magnetic Properties is considering revisions of Definitions of Terms Relating to Magnetic Testing (A 340) and will take action on whether the m.k.s. system of units should be adopted in place of the present c.g.s. system of units or whether they should be used in conjunction. A proposed d-c. magnetization test method using the 25-cm. double lap joint core is under consideration.

Consideration is also being given to the following: (*a*) cross-sectional area for the various test frames for a-c. core loss and permeability, (*b*) sample size for a-c. core loss and permeability with the possibility of using a 1-kg. test specimen rather than 2 kg. now being used, and (*c*) sample selection for a-c. core loss and permeability, primarily for economical purposes, as well as assuring uniformity.

A proposed method for interlamination resistance and a proposed test method for burr height measurements are being developed. The committee is investigating the possibility of establishing a table of magnetic materials giving their various properties.

A-10 Chromium and Nickel Iron Alloys

Studies are under way in Committee A-10 to further standardize certain details of the acid-copper sulfate test and the nitric-hydrofluoric acid test. In addition, data are being accumulated, looking to the revision of the boiling nitric acid test (A 262) to permit the use of apparatus for exposing a large number of specimens in a single container, as described by W. B. DeLong in his paper in the Symposium on Evaluation Tests for Stainless Steels (issued as a separate publication *STP 100*).

A special subgroup is surveying methods for the cleaning of vessels to eliminate surface contamination, foreign metal, scale, etc., after fabrication. This group will also explore suitable methods for inspection after such cleaning treatments.

Subcommittee IV on Methods of Corrosion Testing is arranging for the preparation and subsequent long-time plant-corrosion testing of a large number of welded specimens of several stainless steels given various heat treatments. The results will be correlated with laboratory evaluation tests.

Elapsed-time and rate-of-strain methods of controlling speed of testing will be carried out under carefully controlled conditions to obtain data needed to establish speed limits for testing the austenitic grades of stainless steel. A procedure for etching stainless steels to identify sigma phase without resorting to X-ray diffraction testing is anticipated within the coming year.

Consideration is being given to changes in Specification A 276 to include addition of type 430-F and also the use of a surface hardness test. Consideration is being given to the shape and size of tension test specimens for ½-in. plate.

Committee A-10 is studying the problem of specifications for high-alloy centrifugal pipe castings and has appointed a special task group to deal with this material.

A joint committee (with A-1) has under consideration modification of the Tentative Specification for Seamless and Welded Austenitic Stainless Steel Pipe (A 312

"High Speed Photograph of Hot Bar Being Quenched in Oil"

An interesting photograph displayed in the General Section of the Seventh A.S.T.M. Photographic Exhibit in Atlantic City, by Robert A. Buchanan, United States Steel Corp., Research Laboratories. Mr. Buchanan's print entitled "Final Inspection," a first prize winner in the photographic display, is shown on page 15 of the July, 1950 ASTM BULLETIN.

d is also considering a change in the ll thickness requirements in A 270 r sanitary tubing.

Committee A-10 is inaugurating work determine the possibility of substituting lumbium-tantalum for ferro-columbium all specifications containing ferro-lumbium limits at the present time. his is due to the decreasing availability ferro-columbium and the necessary bstitution of columbium-tantalum.

2 Non-Ferrous Metals and Alloys

Committee B-2 on Non-Ferrous Metals d Alloys is reviewing Specifications 6 – 49 for Slab Zinc (Spelter). The udy of B 101 for lead-coated copper eet is being undertaken to provide rtain methods of test for continuity coating.

Numerous requests have been received the committee to prepare specifica-ons for tin and titanium and considera-on is being given to undertaking work in ese fields, as well as the consideration of ecifications for "jet alloys." (See news ticle at end of this material.)

3 Corrosion of Non-Ferrous Metals and Alloys

Committee B-3 is continuing its study the salt spray test and also the acetic id-salt spray test with special attention eing given to its use for chromium-plated nc-base die castings.

Subcommittee VII on Weather is ntinuing exposure of calibration speci-ens of zinc and steel at several A.S.T.M. mospheric exposure sites. This sub-mmittee is also making a survey of struments and methods for measuring arious kinds of atmospheric pollution at might be expected to affect corrosion.

Part 1 (containing the disk type speci-ens) of the magnesium alloy galvanic rrosion program has been completed d Part 2, consisting of the spool-type ecimens, is expected to be on exposure the near future.

4 Electrical Heating, Resistance, and Related Alloys

Committee B-4 is considering revision the Method of Accelerated Life Test r Metallic Materials for Electrical Heat-g (B 76), mainly in the light of test uipment and test conditions. Further udy is being given methods of test and ecifications for high-temperature alloys electric furnaces. Consideration of a ethod of test for intermittently heating d cooling specimens automatically and vestigation of Alloy Casting Institute sts and report of thermal fatigue and ot gas attack are the basis of future work. he importance of silicon in alloy com-osition as related to corrosion resistivity being studied. The problem of hard-ess testing is active and an extensive eld test program is nearing completion, hich is hoped will lead to specification atus in the near future. Effects of ariances in composition are under con-deration in the study of low-expansion sts such as the invar field test.

Subcommittee VIII on Metallic Materials for Radio Tubes and Incandescent Lamps is continuing extensive work on determination of quality of nickel-base metal for "emitter" purposes for improving chemical test methods, by establishing better tube "prove-in" practice, and continues to establish an improved foundation by means of melt comparison, chemical, metallurgical, and physical test approaches. A tentative method for sag testing has been developed and the group is active on many other problems concerning very fine wire for typical electronic tube and lamp works.

Present investigation of "green rot" effects and behavior of alloys in atmospheres containing sulfur and moisture is continuing.

The Subcommittee on Contact Material is dealing with problems relating to the life test, physical properties, hardness, standardization of forms and sizes, and related subjects. A proposed tentative method of test for determining hardness of contact materials is nearing completion.

B-5 Copper and Copper Alloys

Many standardization matters are being studied in Committee B-5. With a large list of specifications and tests under its jurisdiction there are always studies under way of desirable revisions in existing standards, in addition to its new work.

In the plate, sheet, and strip field, studies include the addition of sawed bar to plate specifications, the use of Rockwell hardness information as a mandatory requirement in eight existing specifications, and the development of certain new alloys.

The work on rods, bars, and shapes includes agreement on additional size ranges in Specifications B 133, agreement on a new aluminum bronze alloy in Specifications B 150, possible revision of requirements for mechanical properties in Specifications B 196 for Beryllium Copper, and the possibility of specifications for forgings.

Subjects involving pipe and tubing include standardizing requirements for automotive and refrigeration service.

Work on castings and ingots will relate to the review of Specifications B 61 for Steam or Valve Bronze and B 62 for Composition Brass or Ounce Metal.

Possible revisions in the requirements for sampling for chemical analysis in specifications for ingots and castings are to be studied.

B-6 Die-Cast Metals and Alloys

Committee B-6 on Die-Cast Metals and Alloys is making progress with the design of a test casting die for hot- or cold-chamber casting of zinc alloys. With the satisfactory development of a method for measuring metal pressures within the test casting die it is planned to study the effect of pressure on the quality of die castings. An attempt is being made to devise a satisfactory compromise whereby a new code identification system, commonly known as the Frankford Arsenal System, will be used for all of the alloys under the jurisdiction of Committee B-6.

The ten-year tests of the magnesium-base and zinc-base alloys exposed at five outdoor and three indoor sites have been completed and the ten-year data are given in the 1950 Report. The remaining magnesium-base and zinc-base alloy specimens will be left exposed until 1959, making a total exposure of 20 years.

B-8 Electrodeposited Metallic Coatings

Specifications A 164, A 165, and A 166 are being revised as they are not applicable to many threaded components because of difficulties with dimensional tolerances. Consideration is being given to a provision in B 141 suggesting agreement between the purchaser and manufacturer on lower minimum thicknesses of chromium in certain cases.

Committee B-8 is also considering the desirability of including metric as well as English units in specifications under its jurisdiction and is also considering the question of significant figures. Progress is being made in developing photographic standards to aid in comparing relative corrosivity of plated panels. Investigation is continuing on the reproducibility of various thickness test methods, that is, magnetic, stripping, microscopic, and dropping tests. Information is being obtained on ductility test methods.

There are in course of preparation Recommended Practices as follows—Preparation of Zinc-Base Die Castings for Plating, Preparation of Copper and Copper Alloys for Electroplating, Preparation of and Plating on Stainless Steel, Preparation of Aluminum for Electroplating and Preparation of Plastics for Electroplating. Consideration is also being given to a recommended practice for plating on lead, tin, and their alloys and on cast and malleable iron.

Plans have been formulated for an extensive program to investigate five types of chromate treatments which will include the exposure of treated specimens to (*a*) industrial atmosphere, (*b*) marine atmosphere, and (*c*) warehouse storage and to study accelerated corrosion in (*a*) 100 per cent humidity, (*b*) pressure cooker, (*c*) salt spray, and (*d*) water immersion. The effect of the hexavalent chromium content of the surface films will also be investigated.

An experimental program is under way to develop possible methods for evaluating the effectiveness of phosphate treatments for corrosion protection and as a surface preparation for subsequently applied finishes.

(OVER)

Cementitious, Ceramic, Concrete and Masonry Materials—"C" Committees

C-1 Cement

As reported in the September BULLETIN a year ago, the emphasis in Committee C-1 is still on performance tests. Much of this developmental work is continuing in the several working subcommittees. The Working Subcommittee on Volume Change and Soundness is considering improvements in the autoclave expansion test, especially precautions which should be observed in the operation of the autoclave; studies of the significance of long-time autoclave test data including the effect of the duration of curing of bars on autoclave expansion; and revisions in the new tentative test method for alkali reactivity (C 227 – 50 T) for further improvement of the procedure in the light of experience.

In addition to further study being made on the method developed for the removal of manganese in cement analyses the Working Committee on Chemical Analysis is planning to sponsor a symposium on flame photometry at the 1951 Annual Meeting as announced in the July BULLETIN. A possible means of avoiding variations in results found in the cooperative tests on lime, mortar bars will be studied by the Working Committee on Sulfate Resistance. Plans for a cooperative study have been completed by the Working Committee on Heat of Hydration for triplicate heat of hydration determinations on three different cements using both the A.S.T.M. standard method and a proposed rapid method. The Working Committee on SO_3 Content plans to complete a draft of a proposed extraction test method in connection with the optimum amount of gypsum in cement. Cooperative tests will be inaugurated by the Working Committee on Air-Entrainment Test Methods to establish data for revisions of the existing tentative test method (C 185). The Working Committee on Coordination of Methods of Tests expects to consider, mainly through correspondence, such questions as flow table specifications, requirements for measurement apparatus for measuring the flow of mortar, standard flow test method, and methods of sampling.

The Sponsoring Committee on Portland Cement plans to assemble strength test data showing the relationship between the specified compressive strength requirements and the results of the compressive strength test as well as the relation between the tensile strength requirements and test results. The Sponsoring Committee on Masonry Cement will consider questions relating to the new flow table specifications, speed of testing, strength requirements, and autoclave tests. Two proposed specifications for portland-fly ash cement and for fly ash, respectively, were distributed to Committee C-1 by the Sponsoring Committee on Blended Cement. The subcommittee expects to submit revised specifications accompanied by appropriate data based upon further suggestions and criticisms submitted.

C-2 Magnesium Oxychloride and Oxysulfate Cements

Following the final acceptance of 14 test methods which will now be submitted to the Society as new tentatives, the committee plans to give further study to methods of test for electrical resistance of conductive floors for hospital operating suites. The applicability of the standard autoclave test for portland cement will receive study in connection with its use with oxychloride cements. New problems to receive attention by the committee include (*a*) factors affecting durability of flooring and methods of tests for such factors, (*b*) methods of measuring wear resistance, (*c*) resistance to deflection and fatigue resulting from intermittent but continued deflections, and (*d*) specifications and methods of test for floor sealers.

C-3 Chemical-Resistant Mortars

Specifications are being prepared and reviewed in draft form covering several types of chemical-resistant mortars including two silicate mortar specifications, one for slow-setting and the other for rapid-setting cements. A review is being made of a large volume of information collected as a basis for formulating test methods and specifications for resin mortars. Further study will be given to test methods and specifications on hydraulic mortars using those already in use for portland cement. Further consideration is being given to definitions and test methods for working and setting times.

The subcommittee on bond strength has outlined a problem dealing with the bond developed between chemical-resistant mortars and masonry units for the purpose of determining suitable specification limits on bond strength. A new subcommittee was authorized to conduct a research program on methods of judging the chemical resistances of chemical-resistant mortars. The results of this program will be of assistance in establishing specifications now under development by the other subcommittees.

C-4 Clay Pipe

It is expected that a task group previously appointed will proceed, during the coming year, with a draft of a specification for extra-strength ceramic glazed pipe. Another task group will review the Recommended Practice for Laying Sewer Pipe (C 12 – 19) to bring this long-standing standard up to date. Continued study will be given to the formulation of specifications for flue linings following the submission of a report indicating this need.

C-7 Lime

A specification to cover the use of lime in leather tanning will receive consideration during the coming year. Methods of testing and analysis on the determination of iron content of limes and a settling test for limes will be studied by the Subcommittee on Methods of Test. The Research Subcommittee will be interested in establishing an improved test for soundness in lime to replace the present pitting and popping test.

C-8 Refractories

Surveys of current practices in the use of refractories in the copper, coke, and flat glass industries are expected to be completed during the coming year with revisions of surveys now published and other new surveys in various stages of preparation. Continued attention has been found desirable in the study of the uniform rate of loading as noted from reports received during the past year from 22 laboratories using hydraulic and mechanical machines. Correlation of these two types of machine loading and ways of specifying rates of loading will be considered. Further investigation into the question of spalling tests on specimens less than $2\frac{1}{2}$ in. thick (C 38) as well as the study of mortars for bedding brick will be made. Progress is continuing on the study of P.C.E. furnaces in which 23 laboratories are cooperating. It is expected that tabulation and correlation of data obtained will be completed this year. The section on chemical analysis is looking further into methods on loss of ignition of magnesia refractories containing lime. Assembled data on rates of loading in modulus of rupture tests will be withheld pending the completion of a similar study of crushing strength.

The Subcommittee on Special Refractories has made assignments for study covering such special refractories as zirconia, zircon, diaspore and bauxite (unfused), mullite, dolomite, spinel, cordierite, forsterite, and several of the carbides. Work on carbon refractories has been deferred pending joint activity in the development of standard test procedures for determining various physical properties of carbon products with the Carbon Committee of Am. Iron and Steel Inst. and the carbon manufacturers group. Cooperative tests are to be made on high-duty fire-clay brick by the Subcommittee on Semi-Silica Brick.

C-9 Concrete and Concrete Aggregates

The research group of subcommittees has many projects in various stages of completion. Considerable data are becoming available to establish frequency of samples and variations in data through the application of statistical analysis. Through a series of discussions the ex-

perience from a large number of investigations has been assembled on the chemical reactions of mineral aggregates in concrete which is expected to lead to further investigations to obtain special data where information is not available. Investigations are planned in the development of tests for modulus of elasticity as affected by the use of admixtures, air-entrainment, and the prestressing of steel. Durability of concrete remains as a subject for much research. Improvements and adaptations of the very interesting and valuable method for measuring the modulus of elasticity of concrete by dynamic means are being developed leading to the testing of structures in place and the application of the method to the determination of the extent of cracking and concrete deterioration.

The subcommittees on specifications and test methods will be concerned during the coming year primarily with revision and review of existing standards. This will include those methods dealing with volume changes of concrete, testing of fresh concrete, water retention, efficiency of methods of curing concrete, and a study of the probable effect of reactive aggregates upon the standard method of test for cement content of hardened portland-cement concrete. The methods of testing and specifications for lightweight aggregates is receiving much needed review and revision in the light of developments in this field. The preparation of a tentative specification for air-entraining admixtures for concrete is under joint consideration by subcommittees of Committees C-1 and C-9. This is closely allied to the development of a specification for fly ash for use in concrete which is also a joint effort of the two committees.

C-11 Gypsum

In spite of the review of all of the standards under the jurisdiction of the committee, resulting in revisions being adopted this year on most of them, the committee will give further attention to additional revisions during the coming year. In particular, rather comprehensive revisions are expected to be made in the standard methods of testing gypsum and gypsum products (C 26), pertaining to chemical analysis. A study is planned, and a report will be submitted for this purpose, on the testing of lightweight aggregates as used with gypsum products.

C-12 Mortars for Unit Masonry

Final action is expected on the acceptance by Committee C-12 of a proposed tentative specification for mortar for unit masonry. The suitability of the Standard Specification for Aggregate for Masonry Mortar (C 144) for specifying stone sand is being considered with a view to revising this specification to include this product. It is expected that there will be activity in the Subcommittee for Admixtures for Mortar in developing methods of test to be coordinated with the work of Committees C-1 and C-9 in this field. Research is continuing on methods of test to determine efflorescence of mortar and to correlate test results with field performance. An enlargement of the subcommittee is desired and further membership is being solicited.

C-13 Concrete Pipe

It is expected that the four A.S.T.M. specifications covering concrete pipe will be revised during the coming year, following complete review by special subcommittees appointed to study specific problems. For immediate revision these several subcommittees will consider: a clarification and revision of the three-edge bearing test; reinforcing to conform to the simplified standards and to provide provisions for adequate welding; absorption test; and provisions for types of cement. In addition a special subcommittee will consider specifications for extra-strength or triple-strength nonreinforced concrete pipe 12 to 24 in. in diameter. A steering committee has been appointed to formulate a long-range program for the committee to study the possible expansion of its coverage to include specifications for irrigation pipe capable of withstanding up to 100 ft. of head as well as other types not now covered.

C-14 Glass and Glass Products

A new procedure for the routine method for determining boric oxide in glass is being studied by the Subcommittee on Chemical Analysis. The possibility of developing standard procedures for softening, strain, and annealing point measurements is being considered by the Subcommittee on Physical and Mechanical Properties. A new section has been authorized in the subcommittee on flat glass to study a proposed method for determining the abrasion resistance of plastics and safety glass.

C-15 Manufactured Masonry Units

Comments from members will be solicited on proposed revisions of the Specification for Hollow Load-Bearing Concrete Masonry Units (C 90) in respect to the moisture content requirement. A final draft of a specification for chemical-resistant units has been distributed to all members of the committee for comments preliminary to a letter ballot. A method of test for acid solubility, which is to be included in this specification, has not been completed and will be given prompt attention by the subcommittee.

C-16 Thermal Insulating Materials

Committee C-16 is continuing its work as reported a year ago. At that time the two groups of subcommittees, namely, on thermal and nonthermal properties, were stressing the development of methods of tests with special emphasis on the inclusion of a significance-of-test statement in each existing or contemplated standard. The effect of moisture on thermal conductivity is receiving increased attention, and a research program is being planned. As a result of very extensive collection of data on field clearances between pipe and insulation, covering thousands of measurements, it is planned to develop a recommended practice for establishing proper clearances.

C-17 Asbestos Cement Products

Committee C-17's primary objective at present is the development of proposed tentative specifications covering asbestos-cement pressure pipe. A task group is developing methods of test to evaluate the "handleability" of asbestos-cement products. Preliminary research is under way in developing data on breaking loads of flat asbestos-cement sheets leading to the development of a specification for this type of product.

C-18 Natural Building Stones

Additional definitions are being considered to include such terms as flagstone, alburene, soapstone, and greenstone. The reaction of the committee is being solicited as to the need for inclusion of grain size definitions in connection with textures of natural building stone. Results of tests are to be checked on the use of 12 by 4 by 1-in. specimens in the modulus of rupture test method (C 99) in order to determine the need for adhering to the established span-depth ratio of not less than 3. The consideration of a proposed specification for exterior marble has been deferred pending cooperative research between the National Association of Marble Producers and Committee C-18. Continued attention, however, will be given by the proper subcommittee to the subject of specifications for all types of natural building stones, including building granite.

C-19 Structural Sandwich Constructions

It is expected that during the coming year Committee C-19 will be in a position to present to the Society for adoption several new tentative test methods as a culmination of its initial efforts since organization two years ago. In considering core materials used in structural sandwich constructions, proposed tentative methods are in varying stages of completion covering apparent specific gravity, thermal expansion, dimensional stability, bond of sheet metal to wood, and flammability. Final review is being given to proposed tentative methods on compression properties, bending-flatwise, shear-flatwise, and shear-edgewise of basic sandwich constructions. In the field of performance, durability, and simulated service tests, several projects are under way including the writing of a tentative procedure for mechanical tests of sandwich constructions at freezing and elevated temperatures; the conducting of round-robin fatigue tests to establish data for comparison of results of different fatigue machines; and a survey of present work being done on exposure of building units.

C-20 Acoustical Materials

The standardization work of this new Committee C-20 has proceeded in a very satisfactory manner and the several subcommittees have already launched projects which, it is expected, will ultimately lead to the adoption of A.S.T.M. standards. The Subcommittee on Sound Absorption has as one of its primary projects a round-robin study of the reverberation chamber method of absorption measurement. Three materials have been selected which will be sent in turn to six reverberation chambers, each lot being checked for uniformity at the National Bureau of Standards. Representative samples will also be saved for a round-robin of small scale impedance tests. Consideration of fire resistance standards will be held in abeyance pending the collection of sufficient data on acoustical materials tested by existing methods developed by other groups including A.S.T.M. Committee E-5.

The Subcommittee on Maintenance is directing its present efforts to the consideration of dirt precipitation with the objective of developing test methods on surface precipitation and breathing. Another current project of this subcommittee involves redecoration of acoustical materials. With 70 per cent of the acoustical materials used being applied by adhesive methods, the initial consideration by the Subcommittee on Application will be in the direction of developing test procedures involving the use of adhesives. A proposed method for measuring light reflectance by use of the Baumgartner Sphere will be reviewed for acceptance as an A.S.T.M. tentative. Preliminary activity in circularizing manufacturers to determine the exact procedures and acceptable limits will be initiated pointing toward the development of methods of measuring hardness by ball indentation. A questionnaire will be submitted to the respective subcommittee members to obtain agreement on the importance of establishing methods of measuring such properties as friability, abrasion resistance, toughness, and transverse strength. A preliminary test procedure is being developed to measure flow resistance using samples of the order of 3 sq. ft. in order to overcome the faults of existing test methods in which sampling errors due to smallness of sample are found and difficulties encountered in preventing air leakage around the edges.

C-21 Ceramic Whitewares

The first tentative approved by the Society in the ceramic whiteware field has been a list of definitions. Additional terms are now being considered. It is also anticipated that tentative test methods on raw materials, including clays and talc, will be completed during the coming year. A round-robin series of absorption tests has been activated to measure fundamental properties of ceramic whiteware products. Other fundamental properties are being studied including impact and chipping tests, modulus of rupture, and thermal expansion.

C-22 Porcelain Enamel

Committee C-22, after effecting its initial organization as a new committee, has inaugurated research activities which during the coming year will call for reports on six projects with such assignments as: the listing of physical properties of raw materials and finished products; adherence of enamel to steel; gas-evaluation effects associated with steel enamel and enamel processing; improved steel surface on fabricated parts; and review of classification of various types of porcelain enamel and ceramic and ceramic-metal coatings including those at high temperatures.

The glossary compiled by the Enamel Division of the American Ceramic Society will be reviewed for adaptation to an A.S.T.M. list with the possibility of adding an additional section concerning trade names.

A priority has been established by the Subcommittee on Test Methods in assigning projects for the development of standards on the following basis: (1) fineness test, (2) fusibility test, (3) torsion tests, (4) water—for mill addition, (5) consistency of slip, and (6) evaluation of enameling iron.

Considerable interest is being shown in the work on standards for finished products with a comprehensive program being considered. Four existing test procedures are being considered for adaptation to A.S.T.M. standards covering acid-resistance test for flatware, boiling acid-resistance test for holloware, warpage test and a falling ball impact test for holloware. Additional test methods to be given further study and consideration include those on gloss, reflectance, thickness, chemical ware, water and alkali resistance, surface, wear resistance, scratch and gouge test, impact resistance for flatware, thermal shock, adherence, and continuity of coating.

Miscellaneous Materials—"D" Committees

D-1 Paint and Related Products

Committee D-1 on Paint, Varnish, Lacquer, and Related Products is one of the most active of the Society's committees as evidenced by the fact that it has been necessary to hold two 3-day sessions of the committee each year during which there are over 70 individual meetings of subcommittees and sections. A number of subjects that are under study in the committee were covered in the July ASTM BULLETIN.

The next meeting of Committee D-1 will be held in Washington, D. C., in March, 1951, in connection with the celebration of the fiftieth anniversary of the National Bureau of Standards.

The various existing methods for chemical analysis of pigments and paints have been undergoing a very thorough study. This resulted in several new and revised methods presented by Committee D-1 to the Society this year. An extensive revision of the present standard methods of chemical analysis of white pigments (D 34) is now being completed. Certain changes to be made during the year in the specifications for aluminum pigments may require modifications of the present methods of analysis. Work will be undertaken on this in order to coordinate the existing standards.

The Subcommittee on Exterior Exposure Testing is revising the tentative method of conducting exterior exposure tests of paints on wood (D 1006) which revision will provide a procedure for testing trim paint, together with a proposed test panel for exterior exposure of trim paints.

Revisions of the specifications for shellac varnishes (D 360) and of the general methods of sampling and analysis of shellac (D 29) are being completed by the Subcommittee on Shellac. It is expected that both of these revised standards will be ready for presentation to Committee D-1 at its next meeting. This subcommittee has been actively cooperating with Technical Committee 50 on Shellac of the International Standards Organization.

The Subcommittee on Pigments is preparing a revision in the specifications for venetian red which will change the maximum calcium carbonate content from 0.1 to 4.0 per cent.

The Subcommittee on Printing Ink has groups now active on the following subjects: definitions, methods review, fineness of grind, rubproofness, printing ink rheology, paper ink relations, and drying time.

The new Subcommittee on Flash Point is giving consideration to the Tag open cup method. It is planned to review the earlier studies conducted in 1933 to 1950 which covered some 1300 tests.

Specifications for methyl isobutyl ketone and methanol have been completed. Also a method for determination of purity of acetone and methyl ethyl ketone are ready for subcommittee letter ballot. An extensive revision of the methods of testing nitrocellulose clear lacquer and lacquer enamels (D 333) is under way.

The Subcommittee on Painting of Metals reported that it has under development a set of standards for ferrous surfaces for painting which includes some 30 colored photographs. A new project is to be undertaken on the painting of aluminum and its alloys.

At the meeting of Committee D-2 in lantic City, June, the 25 or more chnical committees and research visions described their projected activi- s for the coming year. These activities e summarized in the following para- aphs.

Technical Committee A on Gasoline rough its Section V on Specifications, continuing its detailed review of the entative Specifications for Gasoline 0 439 – 50 T). It is still carrying on a matological study in connection with e U. S. Weather Bureau, for the purpose revising the geographical zonings as esently listed, as necessary. It is also anning to review the octane number quirements, and will make recommenda- ons as to the octane number limits and e method or methods to be used for their termination. This committee will also llow, with interest, the experience which gained in the field as a result of the 1950 vision of the specification concerning e maximum allowable vapor pressure.

Technical Committee B on Lubricating ls is expanding its operations by in- easing the scope of its Section on Foam- g so as to include therein the develop- ent of methods applicable to trans- ission oils and other lubricants where aming is a problem. The Section on strument Oils will be working on tests r the oxidation performance and spread- g characteristics of instrument oils. echnical Committee B has authorized Section on Industrial Gear Oils to stribute a questionnaire to various in- rested groups, for the purpose of ob- ining their thoughts on the desirability preparing an industrial gear oil classi- ation system based on viscosity and iscosity limits. The Section on Physical d Chemical Changes is continuing its rk on the development of a method for easuring crankcase dilution in Diesel gines.

Three symposia are being developed for e coming year under the sponsorship Technical Committee B: February, 51—High Additive Content Oils; June, 51—Lubrication Under Extreme Pres- re Conditions; and June, 1951— etting Corrosion, in connection with echnical Committee G on Lubricating reases.

Sections of Technical Committee C on urbine Oils are currently studying the peatability and reproducibility of the rbine oil stability test, methods of test r gas turbine lubricants, the preparation definitions for oiliness and load- rrying capacity, and evidences of non- mpatibility of turbine oils from varying urces.

Technical Committee F on Diesel Fuels currently directing its attention toward e problems of the railroad diesel engine ers. For this purpose, it has organized new section which will facilitate the alysis and solution of fuel problems of terest to the railroads.

Technical Committee G on Lubricating reases—Three groups have advanced eir work to a point where action by Committee D-2 can be anticipated within the coming year. The subjects on which these groups are working are: the development of a procedure for extended working of grease, to be issued as a modification of Method D 217, Test for Cone Penetration of Lubricating Grease; the development, in conjunction with Research Division III on Elemental Analysis, of methods for the separate measurement of inorganic lead and organically combined lead in lubricating greases; and the completion of a new "Definition for Lubricating Grease."

The current work in *Technical Committee H on Light Hydrocarbons* centers about its Section II on Liquefied Petroleum Gas. This group has under study methods on vapor pressure, total sulfur, and sampling liquefied petroleum gas.

Technical Committee J on Aviation Gasoline will complete, during the coming year, the revision of the Tentative Specifications for Aviation Gasolines (D 910 – 48 T). It will also consider the addition of two new grades of aviation gasoline to those already described in the specifications. A new Section on Jet Fuels has been authorized, the purpose of which will be to collect material from all sources on jet fuels, to fill in the gaps in the committee's present knowledge.

Sections of *Technical Committee K on Cutting Fluids* are continuing their work on the evaluation of cutting stability tests, the development of a method of test for active sulfur in cutting fluids, and the development of a procedure for running a tool life test on a lathe.

Technical Committee L on Tractor Fuels is planning to complete its work on the Definition and Specifications for Tractor Fuels, which are being published this year as information.

Technical Committee M on Petroleum Wax, organized during the past year, is now hard at work, with eight working sections. This committee plans to meet with the Technical Association of the Pulp and Paper Industry at Rochester, N. Y., September 13–15, 1950.

Research Division I on Combustion Characteristics has a large number of active projects under way. The more important of these projects, at present, are the improvement of the cetane engine, an evaluation of reproducibility of the F-21 octane method, the development of a pressurized carburetor which will remove barometric pressure as a variable in the operation of the standard octane engines, the development of a micro method for octane determination, and the rewriting of the A.S.T.M. Manual of Engine Test Methods for Rating Fuels.

Division II on Measurement and Sampling having completed its preparation of the first volume of the "Oil Measurement Standards," entitled A.S.T.M. Manual on Measuring and Sampling Petroleum and Its Products, is now in the final phases of its work on Volume II, Oil Measurement Tables, in conjunction with the Institute of Petroleum (London). Volume III of the trilogy, on Tank Calibration, is still in its early stages.

Research Division III on Elemental Analysis lists as its most important new projects the development of electrolytic methods for determining lead in oils and polarographic methods for the determination of tetraethyllead in gasoline. Research Division III plans to sponsor a symposium on the use of the flame photometer, in conjunction with Committee C-1 on Cement, in June, 1951.

These two men are (*from left to right*) C. A. Neusbaum and A. E. Miller, honored at Committee D-2's annual dinner during the recent Society Annual Meeting at Atlantic City. For their many contributions to the work of Committee D-2 in the field of petroleum and its products, they each received a scroll, appropriately worded, to commemorate the tribute from the Committee.

Research Division IV on Hydrocarbon Analysis is working on the development of methods for the hydrocarbon analysis of jet fuels and the determination of olefins in liquefied petroleum gases. It is also attempting to simplify the method of determining aromatics by silica gel adsorption. At the request of Technical Committee H on Light Hydrocarbons, the Section on Spectroscopic Methods for the Analysis of Hydrocarbons will attempt to develop a method for the infrared analysis of amylenes. Other sections of Research Division IV are studying the use of the mass spectrometer in hydrocarbon analysis and the possible consolidation of Methods D 611, Test for Aniline Point and Mixed Aniline Point of Petroleum Products, and Method D 1012, Test for Aniline Point and Mixed Aniline Point of Hydrocarbon Solvents, the latter method prepared by Committee D-1 on Paint Materials.

Research Division V on the Analysis of Fuels.—The Section on Deterioration Products is currently working on methods of test for existent gum or nonvolatile residue in lubricating oils, jet fuels, and other nonvolatile petroleum fractions. A second section is working on methods for the calibration of the centrifuge tubes used in Method D 96, Test for Water and Sediment in Petroleum Products by Means of the Centrifuge.

Research Division VI on the Analysis of Lubricants.—The Section on Neutralization Number and Saponification is planning to give further study during the coming year to Method D 94, Test for Saponification Number of Petroleum Products by Color Indicator Titration, and Method D 974, Test for Neutralization Value (Acid and Base Numbers). The Section on Carbon Residue is continuing its detailed study of Method D

524, Test for Carbon Residue of Petroleum Products (Ramsbottom Carbon Residue), and plans to have a revised version completed during the coming year.

Research Division VII on Flow Properties.—Active projects are directed toward the revision of Method D 445, Test for Kinematic Viscosity, for the purpose of tightening the requirements for apparatus acceptance, and the setting up of a revised method for viscosity blending. This method may be in two parts, one describing a method for routine use, and the other giving a method for exact calculations on blends.

Research Division VIII on Volatility.—One section is continuing standardization and improvement of the Proposed Method of Test for Reduced Pressure Distillation of Petroleum Products, which was published as information as an appendix to the 1950 D-2 Annual Report. Progress is being made in the establishment of an accurate vapor temperature-vapor pressure chart. Individual study is also being given to the possible development of a new crude oil assay method and to the attempted reconciliation of the various distillation methods which have been standardized by Committee D-2 and other Technical Committees of the Society. This latter operation is being sponsored by Committee E-1 on Methods of Testing.

Research Division IX on Color has on its agenda the creation of A.S.T.M. color standards for use in connection with the measurement of the color of aviation gasolines, the development of new specifications and a new source of supply for A.S.T.M. Union Colorimeter glass standards, a possible expansion of the Photoelectric Colorimeter Method which was published as information in 1949 and a revision of Method D 156, Test for Color of Refined Products by Means of Saybolt Chromometer, to include within its scope paraffin wax, pharmaceutical white oils, and petrolatums.

Research Division X on Corrosion Tests is expanding its organization in order to consider the corrosion characteristics of heavier oils, including lubricating oils, cutting oils, and protective oils. The Humidity Cabinet Test which was developed during the war will be considered in connection with the last-mentioned group of oils.

Subcommittee I on Pharmaceutical Tests is working toward improvement in the precision of Method D 937, Test for Penetration of Petrolatum, and is also considering the advisability of setting up a test procedure for determining white oil and petrolatum stability.

Subcommittee III on Petroleum Wax is seriously considering the modification of Method D 721, Test for Oil Content of Paraffin Wax, in order to make it suitable for high-melting-point microcrystalline waxes. A program of cooperative testing is being planned, which will determine the merit of the procedure as revised.

Subcommittee XVII on Plant Spray Oil Tests is just completing a study which will result in the refinement of Method D 483, Test for Unsulfonated Residue of Plant Spray Oils, and Method D 447, Test for Distillation of Plant Spray Oils.

Subcommittee XXIV on Petroleum Sulfonates is planning editorial improvements in Method D 855, Analysis of Petroleum Sulfonates, and has proposed a cooperative program for the purpose of developing repeatability and reproducibility limits for the method. It is also giving preliminary consideration to the advisability of tackling afresh the problem of the determination of inorganic salts in petroleum sulfonates.

Coordinating Division on Significance of Tests.—The most outstanding work being carried out at present is the preparation of the new edition of the pamphlet, "Significance of Tests on Petroleum Products." This work, in close cooperation with the various technical committees, is now about three-quarters complete; the target for publication is the summer of 1951.

Coordinating Division on Test Methods.—The Section on Precision is currently working on a draft of a Recommended Practice on the Use of Precision Data in D-2 Methods.

D-3 Gaseous Fuels

Committee D-3 on Gaseous Fuels has under study a number of additional methods of test.

The committee has in preparation detailed procedures for the sampling of natural gas, manufactured gas, and liquefied petroleum gases. A final draft of the methods for sampling natural gas includes procedures for sampling natural gas containing different gases as contaminants, such as natural gases containing (1) primarily hydrocarbons and nitrogen, (2) hydrogen sulfide, or organic sulfur compounds, or other sulfur contaminants, (3) carbon dioxide, and (4) gasoline and condensibles. This method of sampling is intended to correlate the size or type of sample with the analysis to be subsequently run on that sample. The method includes necessary definitions and descriptions of terms.

The committee would welcome suggestions for improvements in the Tentative Methods for Measurement of Gaseous Fuel Samples (D 1071 – 49 T) issued last year. The very complete set of methods for determining the specific gravity of gaseous fuels (D 1070 – 49 T) also issued as tentative last year are being further studied by the committee and comments and suggestions for their improvement are solicited. These methods cover three procedures for determining specific gravity (1) by direct weighing, (2) by Ac-Me gravity balance, and (3) Arcco-Anubis recording gas gravitometer.

A new method of test for water vapor content of gaseous fuels by measurement of dew point temperature has just been approved by committee letter ballot and will be submitted to the Society during the summer for publication as tentative.

Since its organization in 1935, Committee D-3 has carried on several series of cooperative tests on the complete analysis for chemical composition of gaseous fuels. The wealth of data and information obtained in these studies is serving as a basis for the preparation of procedures for the analysis of gases. A volumetric-chemical method for natural gases just completed, is intended for use when complete composition of the gas is not required. The data obtained by this method are usually sufficient for the calculation of heating value and specific gravity, and are quite satisfactory for the calculation of combustion characteristics.

Methods for the analysis of natural gases and related types of gaseous mixtures by the mass spectrometer are now completed. This analytical method is suitable for determining the complete chemical composition of natural gases and like gaseous mixtures through the C_4 hydrocarbons, including information concerning vapors of heavier hydrocarbons which may be present.

The committee also has under study procedures for the determination of special constituents of gaseous fuels.

D-4 Road and Paving Materials

The Triaxial Institute which is functioning as a project committee of the subcommittee on physical tests for compressed bituminous mixtures is engaged in a comprehensive research program involving development of apparatus for testing procedures applicable to bituminous mixtures and correlation of triaxial test results with surface performance and other methods for physical testing. Papers were presented on this subject at the San Francisco meeting of the Society. Also, some of the papers presented as part of the Symposium on Methods of Testing Soils Under Triaxial Loading at the 1950 Annual Meeting deal with the use of triaxial tests in pavement design. All of the papers will be published together, as a Special Technical Publication, to become available early in the year. This subcommittee is also considering a method for the determination of specific gravity of compressed bituminous mixtures. Cooperative testing to study several features of the ring-and-ball softening point test are planned, to develop a satisfactory method combining two existing methods now published. During the coming year it is expected that the proposed method for the determination of Engler specific viscosity will be recommended for approval. A proposed standard procedure for the direct determination of ash in bituminous materials is being prepared. Requirements are being considered for an additional grade of emulsified asphalt suitable for surface treatment and having rapid setting, high-viscosity properties.

Research work leading toward standardization is one of the major activities of the committee. An extensive program is under way to evaluate the reproducibility of the Tentative Method of Test for Effect of Water on Cohesion of Compacted Bituminous Mixtures (D 1075 T). Of allied interest is a study to determin

he effect of water on bituminous coatings s applied to aggregates. A number of ooperative test programs have been conucted to check present methods of test or the determination of asphalt content f asphaltic road materials. A method as been suggested involving vacuum or team distillation as providing more adeuate information. A method is being nvestigated for determining the abrasion f sand. A better method for the deterhination of specific gravity is under evelopment which will be significant n the control and design of paving mixures. Possible methods for the evaluaion of setting or curing properties of ituminous highway materials are under tudy. Apparatus and procedure in the evelopment of a uniform method for loss n heating of asphaltic materials are reieiving attention. Following the pubcation of the symposium on accelerated ests for durability of bituminous maerials, a subcommittee is now considering he development of a program aimed to btain reliable fundamental information.

D-5 Coal and Coke

Committee D-5 on Coal and Coke is ontinuing its studies on the methods for etermining plasticity and swelling characeristics of coal as regards the reproduciility of the methods now published as nformation. A progress report was also eceived by the committee in June on the tudies being made of analytical proedures for determining nitrogen and ineral CO_2 in coal. This committee as in preparation a series of statements overing the significance of the various ests used in analyzing and evaluating oal and coke which will bring up to date nformation of this type which appeared n the 1930 Symposium on this subject.

D-6 Paper and Paper Products

In addition to a continuing review of arious test methods for paper and paper products that have been adopted by other agencies such as the Technical Association of Pulp and Paper Industry, the Subcommittee on Paper Testing, of Committee D-6, is presently considering the development of methods on the following properties: erasability, stiffness and softness, gloss, lint, chloride content, moisture expansivity, pinholes, zinc pigments, water-soluble matter, and colorfastness to light. Proposed revisions in several existing standard test methods are also under consideration. The Subcommittee on Specifications has been given the project of determining the advisability of writing a specification for paper for multi-wall shipping bags. The Subcommittee on Container Board is currently working on test procedures covering ring crush, flat crush, tensile strength, bursting strength, immersion number, puncture test, and sampling.

D-7 Wood

Further study is contemplated of the Tentative Methods for Establishing Structural Grades of Lumber (D 245 – 49) to consider possible revision and clarification in the light of data from studies under way, including factors affecting the strength of wood in compression. Study is also under way on the revision of Standard Specifications for Round Timber Piles (D 25 – 37). The new Tentative Methods of Testing the Integrity of Glued Joints in Laminated Wood Products for Exterior Service (D 1101 – 50 T) will be studied during the year for possible improvement of the method. Additional definitions and review of existing terms relating to veneer and plywood will receive attention. Special effort will be made during the year to develop the proposed pole testing program as a basic requirement for the rationalization of methods of tests and the development of strength data relating to specifications for treated and untreated wood poles of various species. Closely associated with this activity will be the development of methods of testing crossarms. Consideration of methods of chemical analysis of wood, a new phase of activity in the committee, resulted in the adoption of several new tentatives this year. Work will be continued in developing further chemical procedures.

Subcommittee 1 on Methods of Testing, of A.S.T.M. Committee D-6 on Paper and Paper Products, meets during the A.S.T.M. Annual Meeting. Standing, from *l.* to *r.*: R. H. Carter, the new Secretary of Committee D-6, W. R. (Bill) Willets, D-6 Chairman, and M. S. Kantrowitz, Chairman of Subcommittee 1. Seated, from *l.* to *r.*: First row; R. S. Hunter, L. S. Reid, C. I. Gordon, and John D. Line. Second row: D. C. Wamsley and Harvey Anderson. Behind Mr. Wamsley is Paul Wehmer; next to Mr. Carter, seated, is Henry Harwick; in the back corner is G. H. Mains.

D-8 Bituminous Waterproofing and Roofing Materials

A proposed specification and method of test for insulating siding material will receive further study on a cooperative basis with the Insulating Siding Association. The properties of roofing nails for satisfactory application will continue to receive attention. The use of perforated felt for the purpose of avoiding entrapment of air between layers of built-up roofing has been considered in terms of specifying the arrangement, diameter of opening, and number of perforations per square foot. Three task groups will develop and try out proposed specifications on three types of bituminous cutback coatings for cold application which will include possible consistency ranges. A proposed method of determining preferential wetting of roofing granules with asphalt is in the process of development. Comments are to be solicited on the significance of ductility tests by means of a questionnaire. An instrument for end point determination in connection with accelerated weathering tests has been standardized, and further work will be in process leading toward a development of a tentative method of test.

D-10 Shipping Containers

Performance standards are the center of interest in the committee and several sections of the respective subcommittee will consider various tests. This involves a careful study of test methods which have been adopted to date in order to evaluate results. Of allied interest is the work on correlation of tests and test results. At present, a series of round-robin tests to determine variations in the drum tests and test results (D 782) is being conducted. A new tentative method of testing pallets is expected to be agreed upon during the coming year for recommendation to the Society. The subcommittee on interior packing is expected to complete its projects involving the definition of over 180 terms and the compilation of a bibliography.

D-12 Soaps and Other Detergents

In Committee D-12, the various subcommittees on methods of testing soaps and other detergents have in preparation methods of test for the following: borax in soaps and in combination with synthetic detergents; water-insoluble matter in soaps; flash point and water content of dry-cleaning soaps and detergents; analysis of sodium bicarbonate; wetting properties, and surface and interfacial tension, of soaps and detergents; im-

mersion-corrosion tests for soak tank metal cleaners; rinsing characteristics, buffering capacity, and emulsification properties of metal cleaners. It is expected that at least the methods for analysis of sodium bicarbonate and for testing metal cleaners will be completed during the coming year.

The subcommittee on soap specifications is preparing specifications for grit soaps and for liquid and paste soaps. The subcommittee on specifications for alkaline detergents is investigating specifications for trisodium phosphate monohydrate, sodium orthosilicate, sodium carboxy methyl cellulose, and tetrasodium tripolyphosphate.

D-14 Adhesives

A simplified tension method is being developed to replace the existing standard, and consideration is being given to the determination of tensile strength of relatively low-strength adhesives. In addition to the three tentative methods for determining shear strength of wood and metal already published, a round-robin test is being conducted for determining shear strength of plastic-to-plastic bonds. Another problem to solve is that of the determination of shear strength of adhesives with extensible materials. The Tentative Method of Test for Impact Strength of Adhesives (D 950) is now undergoing further improvement. Round-robin work continues on peel testing. The Subcommittee on Analytical Tests is currently working on methods of determining solids content of adhesives. The Tentative Method of Determining the Effect of Artificial (Carbon-Arc Type) and Natural Light on the Permanence of Adhesive (D 904) is undergoing round-robin testing. Additional methods of determining consistency are receiving consideration. Work on tack has progressed to the point where several instruments for measurement of tack are to be built and round-robin testing will proceed. Work continues on slippage and flow, penetration, and gap filling properties of adhesives.

The committee has setup a procedure to be followed for acceptance of specifications of special problems. Sections have been organized on general utility adhesives, packing adhesives, label adhesives, and book-binding adhesives. A proposed specification on adhesives for acoustical materials is under consideration for final adoption following circulation for comment. Standardization of additional definitions of terms continues. A new phase of work is under way covering electrical properties of adhesives with specific attention being given to insulation resistance and arc resistance.

D-17 Naval Stores

Committee D-17 on Naval Stores at its meeting in June decided to organize subcommittees to consider (1) methods for sampling rosin for analysis, and (2) preparation of purchase specifications for rosins which would be more inclusive than the present Federal Specification for Rosin (LLL-R-626).

Studies of procedures for determining volatile oil in rosin are continuing. Investigative studies are also under way on methods of determining acid number, saponification number, and unsaponifiable matter.

The subcommittee on definitions reported that it has in preparation certain new and revised definitions which cover the terms turpentine, rosin-type samples, and rosin. At its June meeting the committee discussed the problem of recrystallization of rosin recovered from tall oil and decided to consider the reviving of its former subcommittee on crystallization.

D-18 Soils for Engineering Purposes

A proposed method on borings and sampling for soil investigation of embankment materials is being drafted for committee approval. Two other sampling methods to be studied are split spoon sampling and the Shelby Tube (thin wall) methods. Methods for exploration are expected to be given consideration. Revisions will be completed on existing methods of determining physical characteristics of soil (D 422, D 423, D 424, and D 698 T) during the coming year. A program of research and study is being continued in order to obtain basic information on consolidation for the purpose of setting up reasonable and practical requirements and procedures for a consolidation test. At present, attention is being given to the identification and measurement of physicochemical properties of soil, to be followed later by the significance and application of these. Initially the committee will be concerned with the development of procedures for the determination of the constants of composition. Other assignments have been made covering procedures for differential thermal analyses, spectroscopic analyses, spectrographic analyses, petrographic analyses, chemical and X-ray diffraction analyses, and cationic exchange capacity determination.

Identification and classification of soils is receiving attention at present through the medium of a symposium presented at the recent Annual Meeting, and the subcommittee is now working toward the preparation of a tentative on soil nomenclature with respect to grain size.

For news of an important new book on soils, see page 10.

D-19 Industrial Water

Preparation of a Manual on Industrial Water by Committee D-19 is nearing completion and the Manual should be available within the coming year. The text chapters will be supplemented by all the current tentative and standard methods that have been prepared by the committee.

Current projects in the Subcommittee on Sampling include preparation of a proposed method of sampling of water and steam at subatmospheric pressure and proposed specifications for all types of equipment for sampling industrial water and steam.

The Subcommittee on Analysis is continuing work on new methods for the following determinations: copper; clarity, turbidity, and color; chlorine; ammonia; nitrite; fluoride; organic matter; matter extractable with chloroform; gaseous hydrogen; hydrogen sulfide; bromides; and iodides. In connection with turbidity, preliminary studies of nephelometry are being made. Procedures are being developed for hardness (*a*) by calculation from determined calcium and magnesium ions, and (*b*) by a modification of the Schwarzenbach colorimetric titration method. A master scheme for analysis of industrial water is being prepared which will indicate the various determinations that should be made and the order in which they should be performed. A method of chemical analysis of water-formed deposits is in preparation. Also under development is an electrometric procedure for oxidation and reduction determinations. A proposed nonreferee procedure for determining sodium and potassium by means of the flame photometer is being prepared.

The Subcommittee on Classification expects to complete during the coming year specifications for reagent water.

The Subcommittee on Methods of Testing is developing a series of corrosivity tests for tubular materials for various types of equipment and applications in connection with industrial water. Investigation of "corrosion-erosion" effects caused by water is being pursued.

In the Subcommittee on Water-Borne Industrial Wastes, the Section on Critical Constituents reports continued progress on its survey of industries for critical constituents in the industrial wastes, for the purpose of preparing a list of the important and key determinations that should be made on a waste from a particular industry so that the character of the waste may be evaluated. The Section on Methods of Analysis has begun investigations of methods for suspended solids; turbidity and color; dissolved solids; acidity, alkalinity, and pH; oxygen demand; taste and odor; chlorine demand; scum-forming constituents; and toxicity to aquatic life. Work is about to be begun on methods for phenol, cyanides, and sulfur compounds. A section is studying methods already developed by the main D-19 Subcommittee on Methods for Analysis of industrial water to determine their adaptability to industrial wastes. The Section on Sampling is continuing preparation of methods for gaging and sampling industrial waste water and for preservation of samples.

The various projects listed above represent the more important new undertakings out of a total of 56 projects now under way in Committee D-19. In addition to the new projects, several revisions of existing tentatives and standards are being prepared. Scheduled for early completion are revisions in the Method of Sampling Boiler Water from Stationary Boilers (D 860), Method of Test for Total Orthophosphate Ions in Industrial Water (D 515), and Methods of Test for Dissolved Oxygen in Industrial Water (D 888).

-2 Emission Spectroscopy

During the past few years the standardization activity in Committee E-2 has consisted primarily of the collection of some 50 suggested methods, which are expected to be published during the coming year. While further suggested methods are still being collected, the committee now feels it is in a position to again undertake writing tentative methods and it seems likely that several tentative methods will be completed before the next Annual Meeting of the Society.

-3 Chemical Analysis of Metals

Division F on Ferrous Metals, of Committee E-3, has completed a thorough review of the methods for chemical analysis of steel and iron, ferro-alloys, and electrical heating materials. Work is under way on a number of new and revised procedures which include the determination of aluminum in steel, tantalum and columbium in stainless steel, and magnesium in nodular iron. Methods for the analysis of ferroboron and ferrotitanium and for the analysis of molybdenum salts are also being prepared.

Division N is preparing methods for the following determinations: small amounts of aluminum in copper-base alloys, zinc, and lead- and tin-base alloys; analysis of beryllium-copper alloys; tin in antimony metal; small amounts of magnesium, zinc, and silicon in aluminum; new procedures for lead, tin, cadmium, and manganese in zinc-base die-casting alloys; analysis of nickel for electronic uses; and aluminum in magnesium.

Division S on Sampling is undertaking an intensive review of all procedures for sampling metals and expects to recommend revisions in a number of these procedures.

Division G on Analytical Methods is continuing work on performance specifications for analytical balances. This division is cooperating with Divisions F and N in a long-range program planned to provide information on the precision and accuracy of the various E-3 methods.

-4 Metallography

Elsewhere in this BULLETIN reference is made to a new publication resulting from the most important project in Committee -4, on the Electron Microstructure of Steel. This publication with its 47 figures should be of widespread interest and service (see p. 11).

Virtually completed and ready for reference to the Society for approval is the proposed Tentative Method for Classification of Ferrite Grain Size and a second proposal covering Tentative Grain Size Standard for Non-Ferrous Metals (other than copper). Also nearing completion is a Method for Determining the Orientation in the Central Portion of Pole Figures. This latter is of interest in the work on X-ray as is the tentative practice being drafted for Accurate Measurement of Lattice Parameters.

Important work on definitions continues, involving such terms as Electron Diffraction, Phase Diagrams, Grain Size, and so forth. An important problem on which agreement is yet to be reached involves a method for measuring decarburization. In this work there is cooperation between A.S.T.M., Society of Automotive Engineers, and the American Iron and Steel Inst.

E-5 Fire Tests of Materials and Construction

Study is being given to the advisability of not only conducting fire tests on wood stud partitions, loaded to the extent that full allowable stress will be developed in the studs, but also loaded only to the extent contemplated in actual use. The need for a more precise defining of procedure for conditioning specimens for fire testing is under consideration. The need of a standard method of test for evaluating fire-retardant paints is under discussion. Two study groups have been appointed, one to investigate the possibility of simplifying and reducing the cost of performing tests on interior wall and ceiling finish materials in accordance with the tentative procedure recommended by the committee, and the other to investigate and secure, if possible, the necessary funds and personnel for the purpose of conducting further research in connection with the proposed tentative method. Considerable study has been given to the development of a definition for "incombustibility," and a draft of a proposed test has been under discussion. The principal difficulty arises from trying to define "incombustibility." A different approach to the problem is now being considered and a definition for "combustibility" is under discussion. Several testing laboratories have agreed to conduct tests on various materials to provide data from which it is hoped a suitable definition can be decided upon. An advisory study group has been appointed to assist in the development of the necessary data.

E-6 Methods of Testing Building Constructions

The preparation of procedures for the testing of joints in dwelling constructions under shear, tension, compression, and flexure loads will be developed by the subcommittee on connections using small size specimens (not full panels). The Tentative Methods of Testing Truss Assemblies (E 73) will be reviewed during the year on the basis that the procedures may not be restrictive enough. It is expected that agreement will be reached on a test procedure for general structural elements during the year. Methods of test for evaluation of durability have been discussed and an attempt will be made to stimulate interest in the development of satisfactory procedures. In considering the insulation factors in building constructions a group is evaluating a heat flowmeter for measuring this characteristic of insulating materials and wall constructions.

E-7 (*see page 30 for news of this committee.*)

E-9 Fatigue

The Survey Subcommittee of Committee E-9 on Fatigue sent out in January of this year a general questionnaire to 221 laboratories engaged in fatigue studies or projects. There were two purposes in mind: The first was the compilation of a list of fatigue projects so that cooperating laboratories can be informed as to where similar work is being done and thus avoid duplication. The second purpose was to obtain a list of subjects upon which information is needed so that laboratories having available facilities can select an appropriate subject for study. As of June, 98 replies were returned and a report of this survey was included in this year's annual report. Replies are continuing to be received and when the complete results of the questionnaire are known, a revised report or the additional information will probably be published.

E-11 Quality Control of Materials

Committee E-11 on Quality Control of Materials has nine task groups which are actively pursuing projects assigned to them. The work of *Task Groups 1 and 2* has resulted in the completion of a new edition of the A.S.T.M. Manual on Quality Control of Materials which will replace the present A.S.T.M. Manual on Presentation of Data and will become available in September. *Task Group 3* prepared the Recommended Practices for Designating Significant Places in Specified Limiting Values (E 29 – 50). It is giving further consideration to additions and improvements in those recommendations.

The work being done by the other six task groups will eventually result in the preparation of separate sections to be added to the A.S.T.M. Manual on Quality Control of Materials.

Task Group 4 on Sampling Plans has completed a survey of the provisions for sampling which appear in A.S.T.M. standards and tentatives with the intent of disclosing the variety and types of sampling plans classified by types of materials in such a manner as to make their statistical evaluation possible. This survey is now under review in the main committee and will be submitted for publication in a future edition of the ASTM BULLETIN.

Task Group 5 on Planning Interlaboratory Test Programs is developing a set of recommendations intended for use in planning for the collection of multi-source data. These recommendations will be of particular assistance to the other A.S.T.M. technical committees. The task group is making use of material now appearing in the A.S.T.M. Tentative Recommended Practices for Planning Interlaboratory Testing

of Textile Materials (D 990 – 49 T) prepared by Committee D-13.

Task Group 6 is developing a brief presentation on the distribution of averages of samples of size n from a known distribution. This will cover the determination of size of sample that must be taken for a desired precision of an average.

Task Group 7 on Bulk Sampling is studying problems of sampling materials that occur in bulk form or in packages, with the aim of estimating, at minimum cost, measurable characteristics of a quantity of material in order to get some prescribed limit of error with an assigned probability.

Task Group 8 on Precision and Accuracy is considering the use of such terms as "precision," "accuracy," "reproducibility," "repeatability," "consistency," "reliability," "calibration," and other allied terms connected with measurement of error, and as a result will make a report with recommendations as to those terms which appear desirable and necessary for standardization. It proposes to consider a precise definition for each term selected for standardization and give, if feasible, a simple algebraic or numerical measure of each term standardized.

Task Group 9 is preparing a guide for curve fitting in the case of linear relationship, including a discussion of methods of determining and expressing the limits of uncertainty of the calculated relationship.

Committee B-2 to Work on Titanium

THE A.S.T.M. has delegated the responsibility of developing specifications and methods of testing titanium metal to Committee B-2 on Non-Ferrous Metals and Alloys.

Standards will be developed since the development of titanium may foreshadow advancements in supersonic aircraft, rocket, and gas turbine design—and foreseeable improvements in thousands of other industrial and consumer products.

Titanium is the fourth most abundant metal in the earth's crust. Its density is between that of aluminum and stainless steel. This property, in conjunction with its high tensile strength (alloys up to 230,000 psi. have been made and an alloy of 150,000 psi. and 15 per cent elongation is now being produced for various experimental applications) suggests many uses. The metal has the additional desirable quality of resisting corrosion by acids, alkalies, and, what is more important to the Armed Services, salt water.

Although the present price of forgings is about $10 a pound and sheet about $20 a pound, the demand is still greater than the supply.

In view of the experimental work which has been done, the increasing supply and demand for the metal, and its constantly decreasing cost, it is apparent that it may have widespread applications.

Radiographic Testing Recommendations Now Available

Comments Solicited by ASTM Committee

ALL persons interested in radiographic testing are invited to submit criticism and comments on a proposed Recommended Practice for Radiographic Testing which has been developed after intensive work by Committee E-7 on Non-Destructive Testing. The project is being handled in its Subcommittee I on Radiographic Procedures.

The proposed Recommended Practice is an expansion of material formerly included in the former methods of radiographic testing E-15 which have since been withdrawn.

At its meeting during the A.S.T.M. Annual Meeting in June, Committee E-7 voted that the new document should be distributed for criticism, and copies are now available from A.S.T.M. Headquarters at 50 cents each. The proposed Recommended Practice has been duplicated and covers 27 pages.

The subject matter of the proposed recommendations is divided as follows:

PART I. EQUIPMENT AND CALIBRATION

A. Radiation sources
B. Radiographic equivalence factors
C. Film
D. Screens
E. Radiographic contrast
F. Focus-film distance
G. Exposure charts and exposure calculators

PART II. EXPOSURE FACTORS AND ARRANGEMENTS OF PARTS

A. Preliminary study
B. Technique
C. Identification and arrangement of parts
D. Technique card file

PART III. PROTECTION AND CARE OF FILMS

A. Storage
B. Protection from X-rays
C. Protection from gamma rays
D. Safelight test
E. Cleanliness

PART IV. PROCESSING FILMS AND VIEWING RADIOGRAPHS

A. Preparation
B. Start of development
C. Agitation
D. Rinsing
E. Fixing
F. Washing
G. Drying
H. Specific processing recommendations
I. Testing developer
J. Viewing radiographs
K. The viewing room

PART V. RECORDS, REPORTS, AND IDENTIFICATION OF ACCEPTED MATERIAL

A. Records
B. Reports
C. Identification of completed work

An effort has been made to include specific instructions for carrying out the various steps of the radiographic process according to the best practice but without the usual explanatory material which is found in the literature. The subcommittee recognized at the start, however, that it could easily overlook features which might be important, or perhaps include unimportant material. Accordingly, it requests that readers submit constructive criticism. All persons interested in industrial radiography are urged to obtain this document by writing directly to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa. Criticisms should be addressed to the Chairman of the Subcommittee, Dr. H. E. Seemann, Research Laboratory, Eastman Kodak Co., Kodak Park, Rochester 4, N. Y. To receive consideration for the first revision, *comments must be in by October 16, 1950.*

Refractories

BY James R. Coxey, this is a 162-page textbook for operating plant personnel, engineers, and metallurgists in plants manufacturing refractories, and also in plants using refractories. The book is designed to provide a useful, practical, technological background in refractories.

Explaining the what, where, and why of refractories, the text discusses the merits of the various types of refractories, factor affecting refractory life, refractory mortars, refractories manufacturing processes, refractories for the major industrial consumers, and the testing of refractories.

Numerous A.S.T.M. diagrams and photo-cuts on refractory materials have been used in the several chapters to further the completeness of the work.

A registered professional engineer, a graduate of The Pennsylvania State College and holder of two academic degrees, Professor Coxey wrote the book with the expert assistance of key operating plant personnel and research directors in both manufacturing and consuming industries. The original notes have been thoroughly tested as text material.

Employees in plants where refractories are manufactured and employees in plants where refractories are of vital importance (such as the metallurgical, glass, lime, and cement industries, etc.) will probably find the book equally useful.

The book, "Refractories," is $2.50 and can be obtained from the Mineral Industries Extension Services, The Pennsylvania State College, State College, Pa.

Industrial Water and Water-Borne Industrial Waste[1]

By Max Hecht[2]

The American Society for Testing Materials numbers among its 70 main technical committees several that are preparing standard methods and specifications for the evaluation of those natural resources which find industrial applications. A.S.T.M. Committee D-19, organized in 1933, deals with the examination of one of these resources—water in the area of industrial operations. The organization and activities of Committee D-19 are summarized in this paper.

The concept that "water is an engineering material"[3] may be explained by the following:

"Industrial water may be considered to be the aqueous medium (untreated, treated, or both) circulating in the industrial intraplant systems and equipment and used in both direct and indirect processing operations for production purposes.

"Water-borne industrial waste or industrial waste water may be interpreted to be a substance (solid, liquid, or gaseous) resulting from an industrial operation or process and discharged into the water therefrom."

Committee Integrated Program and Personnel

The fully integrated committee program includes three parts:

1. Preparation of the A.S.T.M. Manual on Industrial Water.
2. Sponsoring of Symposia and Round Table Discussions on timely subject matter at water sessions of the Society.
3. The preparation of Standard methods and specifications.

The over-all program has been designed to meet the needs of industry and is being carried by men from industry. These industrial needs have attracted approximately 100 members, drawn largely from diversified industries, but working with representatives from national societies, research organizations, and technical schools; consulting engineers and chemists; and various federal agencies which are interested in the area of the committee's activities. These men,[4] all of whom are active in the program, represent the technical fields of Chemical, Mechanical, and Corrosion Engineering; Analytical, Industrial, and Physical Chemistry; Microscopy, Mineralogy, and Petrology.

Program—Part 1: The A.S.T.M. Manual on Industrial Water will be completed in the near future and will be recommended to the Society for publication. It is designed for use by executives, industrial water engineers, chemists, and plant operators. Chapters of the initial edition are:

I. Composition of Industrial Water Supplies and Water-Formed Deposits.
II. Uses of Industrial Water.
III. Difficulties Caused by Water in Industry.
IV. Treatment of Water for Industrial Use.
V. Sampling of Industrial Water and Water-Formed Deposits.
VI. Analysis of Industrial Waters.
VII. Identification of Water-Formed Deposits.
VIII. Analysis of Water-Formed Deposits.
IX. Glossary of Terms and Data.

Program—Part 2: Papers presented at Society Annual Meetings have been sponsored by the committee for many years. The topics[5] in general, have presented the results of investigations on water methods. In some instances the topics have pointed to the need for research in the industrial water field; some of the methods produced by the committee had their genesis in these technical papers.

Program—Part 3: Preparation of Standard Methods and Specifications is the primary objective of the committee. It will be recognized that by the production of Methods the committee is implementing its over-all program. This includes the preparation of methods for sampling of industrial water, industrial waste water, and water-formed deposits. In the area of analysis it includes methods using colorimetric, electrometric, gravimetric, and titrimetric procedures and special techniques that involve the application of various forms of the microscope, the spectroscope, the spectrograph, and X-ray diffraction equipment. The committee has also prepared methods and specifications for evaluating the corrosivity of water and for reporting results of analysis.

Published Methods

The 31 A.S.T.M. Methods[6] prepared by the committee, adopted and published by the Society as Tentative or Standard, are being currently augmented.[7] Forty-four proposed methods are being prepared by the various subcommittees. For the benefit of those who are primarily interested in bacteriological tests of potable water supply and sewage examinations the reader is referred to "Standard Methods of Water Analysis," Ninth Edition, published by the American Public Health Association, 1946.

A.S.T.M. Methods Produced by Committee D-19

Number of Standards	Subject
3	Sampling of industrial water and steam
1	Sampling water-formed deposits
22	Analysis of industrial water
2	Testing corrosivity of industrial water
1	Reporting results of industrial water analysis
1	Standard definitions on industrial water
1	Chemical analysis of and reporting results of examination of water-formed deposits

It is axiomatic that the analytical report is valuable only when the analysis is made on samples that are properly taken from the streams circulating in the intraplant water systems and are representative of the concentrations. Principles of fluid flow have been used in the preparation of A.S.T.M. methods for sampling of industrial water. For the sampling of water-formed deposits, that is, biological products, slimes, scales, sludges, and corrosion products, the procedures have been built around the variety of experience of the entire committee membership, many of whom have intimate contact with these industrial problems.

The primary consideration of the committee in the production of analytical methods is to write a procedure for the analysis of a constituent or substance that may be present in wide ranges of concentration. It is obvious

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[1] Comment is invited on the following review as well as on the methods produced by Committee D-19 on Industrial Water and referred to elsewhere in the text. All comment should be addressed to the Executive Secretary, Am. Soc. Testing Mats., 1916 Race St., Philadelphia 3, Pa.

[2] Chairman, Committee D-19 on Industrial Water.

[3] See Appendix for general scope.

[4] The complete personnel appears in the A.S.T.M. Yearbook.

[5] A complete listing of the papers appears in "A.S.T.M. Standards on Industrial Water," December, 1949. These papers have been published also in the *Proceedings* and a few in the ASTM Bulletins.

[6] Consult 1949 Book of A.S.T.M. Standards, Part 5, pp. 1431–1558.

[7] Preprinted "Report of Committee D-19 on Industrial Water, No. 98," to be published in *Proceedings*, Am. Soc. Testing Mats., Vol. 50, 1950.

that the ranges of concentration differ for various industrial operations and are not the nominal concentrations that occur in natural water supplies. Many of the A.S.T.M. analytical methods for industrial water analyses differ markedly from procedures for the analyses of potable water supplies. This A.S.T.M. committee also has not hesitated to apply methods requiring special instruments formerly used primarily in research. These instruments have been simplified for use in industrial operations. Thus it has been feasible to supplement classical wet analytical procedures.

The committee's analytical methods include "referee" procedures of maximum precision and accuracy for use in research investigations and for the checking of contract specification requirements. These referee procedures are supplemented with nonreferee procedures of lesser precision and accuracy for use in plant control operations.

The committee's activities in the Field of water-borne industrial waste[7-10] are parallel with its activities on industrial water and are supplemented with

(*a*) the survey of industries to secure an inventory of "critical constituents" produced in its industrial waste,
(*b*) the necessary methods for gaging the intraplant waste waters, and
(*c*) the preparation of methods for preservation of the secured sample, to maintain the integrity of its constituents in the interval between sampling and analysis.

Committee Organization[11]

The production of the committee, as described under Part 3, is secured by means of seven subcommittees—two of these are administrative, the balance are technical. Each member may be assigned to one or more of the following subcommittees:

I. *Advisory* (*Administrative*).—This subcommittee includes as members the elected Committee Officers of Committee D-19 and the appointed Subcommittee Chairmen and Secretaries.
II. *Editorial* (*Primarily Administrative*).—This subcommittee consists of 22 members. Its Section "A" is completing the preparation of the A.S.T.M. Manual on Industrial Water, discussed under Part 1 of the committee program.
III. *Methods on Sampling* (*Technical*).—This subcommittee includes 48 members. Its three sections are:
A, On Sampling of Water.
B, On Sampling of Water-Formed Deposits.
C, On Sampling of Steam.
IV. *Methods of Analysis* (*Technical*).—This subcommittee includes 76 members. Its four sections are:
A, On Analytical Methods.
B, On Electrometric Methods.
C, On Special Methods.
D, Chemical Analysis of Water-Formed Deposits.
V. *Classification* (*Technical*).—This subcommittee includes 35 members. Its two sections are:
A, On Classification.
B, On Nomenclature and Terminology.
VI. *Methods of Testing* (*Technical*).—This subcommittee includes 41 members. One section is:
A, On Corrosivity.
VII. *Water-Borne Industrial Waste* (*Technical*).—This subcommittee includes 69 members. Its four sections are:
A, On Critical Constituents.
B, On Analytical Methods.
C, On Sampling and Gaging of Waste Water and Preservation of Samples of Water-Borne Industrial Waste.
D, On Reporting of Analysis.

Committee Report

The annual reports of Committee D-19 on Industrial Water, as printed in the Society's *Proceedings*, include, the recommendations to the Society concerning new methods and revisions of existing Tentatives and Standards, and a summary, of the activities of all subcommittees, in which there is discussed pending and future projects. The adopted methods and revisions are published in the 1949 Book of A.S.T.M. Standards, Part 5, and its Supplements which will be published in 1950 and 1951.

APPENDIX

Scopes of Committee D-19 on Industrial Water and Its Subcommittees

Committee D-19 has as its purpose the study and description of industrial water as an engineering material, including terminology; methods of sampling, analysis, and testing; interpretation of results of analyses and tests; classification; and specification. The principal function of subcommittees (other than the Advisory and Editorial Subcommittees) shall be to study methods of sampling, analysis, and classification, interpretation of test methods and terminology, and to recommend new tentative or standard methods and revisions of present tentative or standard methods as need arises. The specific functions of the following subcommittees are:

(*a*) *Subcommittee I, Advisory.*—The purpose of this subcommittee is the executive direction of the committee and it shall include acting on recommendations and matters referred to the officers from the Society as well as from Committee D19.

(*b*) *Subcommittee II, Editorial.*—The function of this subcommittee is the preparation in standard form of specifications and methods of sampling, analysis, and testing that are approved by the committee, including interpretation of the results of individual test methods and the terminology employed in the description of the methods.

Subcommittee II shall report to the Advisory Subcommittee its recommendations concerning any material that is submitted to it for review and editing, where such material is intended for presentation at any meeting of the committee and the Society, and when it is intended for publication in any of the Society's publication mediums.

(*c*) *Subcommittee III, on Methods of Sampling.*—The scope of this subcommittee includes the preparation of standard methods for the sampling of water in its various states, and of the deposits resulting from or incident to the industrial use of water. Within its province is the sampling of:

Meetings of several of the Sections and Subcommittee of Committees D-19 on Industrial Water were held in Atlantic City. This is a meeting of Section B, Methods of Analysis and part of Subcommittee 7 on Water-Borne Industrial Waste. Front row, from *l.* to *r.* Section Secretary R. W. Haywood, Jr.; Section Chairman Roy F. Weston; M. F. Madarasz and Claude K. Rice. Extreme left: Robert E. Price, next (with pipe) James K. Rice. Center: L. C. Flickinger; behind him, F. N. Alquist; behind Mr. Haywood, B. W. Dickerson; behind him, J. K. Rummel. Others in the group include W. J. Sloan (behind Messrs. Weston and Madarasz) and in the back corner is L. Drew Betz, Chairman of Subcommittee 7. For a distinct picture of Mr. Betz, see July Bulletin, page 9.

[8] "New Subcommittee on Water-borne Industrial Wastes," ASTM Bulletin, No. 153, August, 1948, p. 34.
[9] "Report of Committee D-19 on Industrial Water," *Proceedings*, Am. Soc. Testing Mats., Vol. 48, 1948, and Vol. 49, 1949.
[10] "Round Table Discussion on the Need for Standards for the Examination of Water-Borne Industrial Wastes," ASTM Bulletin, No. 162, December, 1949 pp. 35–46.
[11] See Appendix for scopes of subcommittees.

(1) Surface and subsurface water supplies and water in tanks.

(2) Water and water vapor flowing in pipes.

(3) Water and water vapor subjected to atmospheric, subatmospheric, and superatmospheric pressures and/or atmospheric, subatmospheric, and superatmospheric temperatures. Methods to be submitted shall include those for natural and processed waters for industrial uses, for water vapor, and for condensation products of water vapor.

Also within its province is the sampling of scales, corrosion products, or organic growths formed during the industrial use of water.

(*d*) *Subcommittee IV, on Methods of Analysis.*—The scope of this subcommittee includes the collection and verification of data for use in the preparation of standard methods of analysis of water in its various states and of the deposits resulting from or incident to the industrial use of water. It shall furnish methods for the determination of the various ions, dissolved gases, and other substances in water having both a varied hydrogen-ion concentration range and a varied dissolved salt content. These methods should be distinguished for use in concentrated products, natural supply, and processed supply. Both referee and field methods shall be formulated.

Subcommittee IV shall also furnish methods for the identification by special means such as the microscope, X-ray, or spectrograph, of the constituents of deposits from water.

(*e*) *Subcommittee V, on Classification.*—One function of this subcommittee is the development of standard specifications for expressing analytical data. A second function is the development of standard methods for classifying the probable behavior of water with respect to corrosion, deposition of solids when heated or processed, or other effects which are significant in determining the suitability of water for industrial use.

(*f*) *Subcommittee VI, on Methods of Testing.*—The scope of this subcommittee comprises the formulation of standard methods of measuring the behavior of water with particular respect to corrosivity under various conditions of use. Methods of testing to be sponsored by this subcommittee shall be considered to be procedures which will evaluate the combined effects of water under a specific set of conditions and not necessarily the evaluation of the effect of a specific constituent of the water.

The subcommittee shall survey the various methods of testing and the data obtained by these methods for the corrosivity of water in its various states, with a view to the formulation of a manual or guide consisting of the description of each test, its application to given conditions, and the results to be observed by its use. The subcommittee shall likewise survey methods of testing the tendency of water to form deposits under conditions of industrial use, including sedimentation and flocculation as well as the formation of scales, and organic growths.

(*g*) *Subcommittee VII, on Water-Borne Industrial Wastes.*—The scope of this subcommittee comprises the preparation of standard methods for sampling of industrial waste water, the preservation and analysis of samples, and the methods of reporting the results of such analyses. There are four sections:

Section A on The Critical Constituents of Water-Borne Industrial Waste whose scope is the selection of a key determination on a specific waste by which it may be evaluated.

The function of Section A is to prepare a list of the type of waste produced by a given industry, together with the most important constituents which may be considered as typical of all plants in that industry, and hence, may be used as evaluation of such wastes as objectionable discharges.

Section B on Methods of Analysis for Industrial Wastes whose scope is the preparation of all analytical methods to be used in the detection, identification, and evaluation of the components of water-borne industrial wastes.

Section C on Methods of Sampling, Gaging, and Preservation of Samples whose scope is to prepare methods of sampling, gaging of flow, and preservation of samples during the period of transportation and analysis.

Section D on Methods of Reporting Results of Analysis whose scope is to prepare methods of reporting analyses dependent upon the type of waste, etc.

You Made Me What I Am Today (I hope you're satisfied) or 25 Years on the ASTM Chain Gang

By Robert Burns[1]

EDITORS NOTE.—All committee members, particularly committee officers, will probably enjoy digesting this slice of reminiscence by Robert Burns, a former chairman of Committee D-20 on Plastics.

SCENE 1—The Nursery

A.S.T.M. was in a pretty sorry state in 1924 when I received my first assignment—to "assist" in the preparation of a test method for measuring the insulation resistance of solid dielectrics. Knowledge was at a low ebb, progress had come to a halt (if indeed it had ever started) and the Society membership consisted of arthritic old duffers (some nearly 50 years old) who sat around all day discussing technical details when they could just as well have written a dozen or even a hundred standards. It was quite obvious to me that the measurement of insulation resistance was merely an excuse for bringing my immeasurable talents to the more holy cause of Raising the Society to the Pinnacle of Perfection.

I smothered my embarrassment when they appointed me Fourth-assistant in Charge of Commas and Semicolons. Honest Abe Lincoln started at the bottom, so could I. After two years I was given by first technical work, dusting off the galvanometer each morning and composing Note 24 which read, "See page 1396 of *Proceedings*." My progress was slow but so was George Washington's at Valley Forge. "Press on to the end for the prize" was my motto, but my pride took quite a beating when I learned that the Committee's booklet had increased by 50 pages and I hadn't written a single one of them. Well, why worry, those new methods were probably no good any way!

To commemorate my fifth anniversary in Society work I was made Fourth Deputy of Section 496 of Subcommittee 27 in Charge of Numbering Paragraphs. Any ASTMer will appreciate my elation. The technology of the method itself is not important; one may specify a test tube when he should have called for a 12-lb. sledgehammer, but to get the paragraph numbering all loused up is an unforgivable crime. My success as a numberer was so outstanding that in my tenth year I was made a Section Head in charge of Maximum Time Between Opening of Oven Door and Removal of Specimen.

Appointment as Section Head stamped me as a technologist of the first magnitude. My first technical paper, "Left-Hand Hinged Oven Doors *versus* Right-Hand Hinged Oven Doors —a Study in Scientific Overnatrics," was immediately accepted by the Society for publication. With due modesty I looked forward, perhaps in a few years, to becoming a subcommittee chairman.

However, all was not well. Whereas, at the start, I considered myself a

[1] Bell Telephone Laboratories, Inc., Murray Hill Lab., Murray Hill, N. J.

dynamic fireball when compared to the other members, with their slow-motion characteristics, it now appeared that both parties were approaching a common speed, give or take a few miles per hour. After considerable soul-searching the conclusion was inescapable that most of the change in speed was due to my deceleration. This was alarming, but was due no doubt to the Society's lack of proper appraisal of my scintillating qualifications. Now that I had become a Section Head, my indubitable administrative abilities could be applied to the main problem, making the Society *spring into life!*

SCENE 2—The Executive Bridge

A Section Head's principal duty is to remain calm and undisturbed when the method over which his section has labored for months is torn to fragments by the Subcommittee. The harmless-looking phrase "referred back to the Section" really means that the Subcommittee thinks the method smells to high heaven! This is easily understandable. Subcommittees are invariably composed of stuffy, high-handed characters who, remembering the punishment they took when they were Section Heads, are simply venting their vindictiveness on the younger more progressive members. Whether the method is good or bad is irrelevant; the primary attribute of a subcommittee member is the ability to vote a resounding NO regardless of the merits!

Upon my completion of five years as Section Head the score stood: Methods Accepted by Subcommittee—0, Methods Rejected—92. Statistically the record was not bad. If you multiply the number of rejected methods by $\sqrt{-1}$ and divide by the root mean square of the tensile strength you will see that what the Society suffered from was too many vacuum-brains on the Subcommittee.

Comforted by the statistics I remained outwardly calm (though seething inside) and was rewarded by promotion to Subcommittee Chairman.

Appointment as Subcommittee Chairman automatically made me a member of the Advisory Committee. Now I was a member of the brass and could really start some reforming. My first thought was to reform the Sections. From the eminence of my new position I could see them in their true light. Rather than being youthfully progressive, they now appeared as an undisciplined squad of blatherskites, strong on talk, weak on intelligence, and with fanatical desires to write test methods suitable only for the comic books.

It was pleasant to see the Section Heads squirm as we voted NO. With fiendish delight we'd throw the hard work of many months out the window. Once in a while, when confronted by reams of incontrovertible data, we were forced to vote affirmatively but these were rare occasions, and were looked upon as merely isolated dark clouds in an otherwise bright sky.

Of course I didn't forget my reform program on a broader scale. Actually, my fellow members on the Subcommittee, and my associates on the Advisory Committee were rather dull fellows. Most of them, when faced with very convincing evidence in the form of round robins, etc., were inclined to weaken and vote YES. Some of them even went so far as to defend a Section Head when he staggered in with a heavy load of data.

Reforming these fellows was not easy. All were top-drawer professionals with national and international reputations. Nevertheless they had a childlike faith in data, evidence, logistics, peaceful cooperation among and between industries, and similar trivial matters. I contended that such things must be cast aside if we wanted the Society to be the Hot Rod of the 20th Century.

After five years of hard fighting it was time for another self-inventory and the results were disturbing. First, I found myself voting YES quite frequently, an obvious sign of mental degeneration. Second, my associates increased in stature; I looked with admiration on their maturity of judgment, their technical skill, their manly qualities, their ability to submerge personal interest for the good of the Society. I formerly thought such characteristics were identified with sissies, now I was actually admiring them!

This was a pretty mess! The Great Reformer was not only mentally weak but becoming a soft-hearted sentimental slob as well!

With what little strength remained I determined to fight on. I called my fellow members of the Advisory Committee together and outlined my plans for a general revitalization of the whole Society, in fact of the whole nation, and if we had any time left over, of the whole world. The members listened respectfully. Then one fellow spoke up, "I'm sorry but your plans will have to wait. We've just elected you Chairman of the Committee."

SCENE 3—The Old Folks' Home

Leave us face it, when a man is elected Chairman of one of our Technical Committees his days as a reformer of the up-and-at-'em school are over, even though *rigor mortis* may not have actually set in. Technically he's a dead duck. The grass-roots boys on the sections consider him an old fuddy-duddy who was supposed to be an expert on something or other 20 years ago. So he can't reform the technicians. The Society big shots, those fellows who wear special badges at the Annual Meetings and look as though they just swallowed a sour pickle, look upon the new Chairman as a bumptuous upstart; naturally he can't reform them. So he spends his time presiding over dignified meetings, reading endless reports, and receiving polite letters from Headquarters informing him that there will be a meeting in Switzerland on self-bailing thermometers. Does he have any comments?

My term as General Chairman was singularly successful. I evoked 32,914 "ayes" from the members and only a handful of "noes" which were immediately consigned to the garbage pail, unless accompanied by good reasons, in which case they were put in the more highly decorative trash basket. I gave speeches which were masterpieces of equivocation and circumlocution. Secretaries addressed me with proper respect; even the stately Directors bowed discreetly as I passed.

After serving for six years as Chairman I was eased out by a gentle process known as Injecting New Blood Into Our Committee. But a very nice thing has happened. I was not cast aside like an old shoe—far from it. Out of the kindness of their hearts the lowly section members had welcomed me back and have assigned me to a section in charge of Preparing Three Test Methods Where One Would Plainly Suffice. Thus endeth the first 25 years in A.S.T.M., the cycle is complete, I'm back where I started.

What about my reform program? Well, sir, right now I'm busy getting a couple of new test methods on the books. I know they're good because I wrote them myself. But I've got to get them past a Section Head who is a notorious lame-brain and a Subcommittee Chairman who is practically illiterate on technical matters. Say, why wouldn't it be a good idea to reform these two fellows and step up the tempo of progress? Why not reform the Society, the nation, the world. Oh, brother, here we go again!!

Manhattan Bus Terminal[1]

By John M. Kyle

(An Abstract)

Before describing the ort Authority Bus Terminal, on the sumption that many of the A.S.T.M. embers are not familiar with the Port New York Authority, it may be well present a brief outline of its activies.

The Port of New York Authority is bi-state agency created by a compact etween the states of New York and ew Jersey in 1921. Its purpose is to romote the construction and operation terminal and transportation facilities the Port of New York District. This istrict roughly encompasses a 25-mile adius with the Statue of Liberty as the entral point. The Port Authority is a elf-supporting organization with no ower to tax.

The Port Authority does not compete ith private enterprise and undertakes o provide only those essential terminal nd transportation facilities which, beause of their marginal nature, could ot be financed by private business. he Port Authority is headed by twelve ommissioners—six from the State of ew York and six from the State of ew Jersey, appointed by the respective overnors. These Commissioners reeive no compensation and give their me and energy as a matter of public ervice. The staff of the Authority is eaded by the Executive Director, ustin J. Tobin. There are approxiately 3000 men and women now emloyed by the Port Authority. Some f the Terminal facilities included in the cope of the Port Authority manageent are Holland Tunnel, Lincoln Tunel, Grain Terminal, three Staten sland Bridges, George Washington ridge, Inland Terminal, two Truck erminals, and the four major airports n the metropolitan area.

The Port Authority Bus Terminal ow under construction will occupy the ntire block between Eighth and Ninth venues and 40th and 41st Streets, anhattan. It will be the largest and ost modern bus terminal in the world —a great new $24,000,000 landmark in he heart of New York City. The bus erminal will help to relieve traffic ongestion on the west side of Manhatan Island and will provide a centrally ocated, spacious and comfortable "Union Station" for approximately 30,000 passengers resulting from the daily arrival and departure in Manhattan of 2500 inter-city buses. Eighty-five per cent of these buses are commuting services and are used twice each day by about 60,000 people traveling to and from their homes in New York and New Jersey suburbs.

The Lincoln Tunnel will have a direct access ramp to the roof and suburban bus levels of the terminal, as well as approaches which will permit local traffic to get to the roof parking level. The long-distance buses will enter on the 40th Street side and use the lowest level of the bus terminal and depart through the 41st Street exit. On the roof of the terminal, there will be a public automobile parking area for approximately 450 cars, with a waiting room for parking patrons and escalators to the main concourse. During winter months, the vehicular ramps will be kept free of snow and ice through radiant heating in the roadways. Thirty-one conveniently located moving stairs will carry the flow of traffic between floors in the terminal. There will be a direct connection with the Eighth Avenue subway and a passage connecting with the Times Square stations of the IRT and BMT subways.

Construction Materials Specified by A.S.T.M. Standard:

Excavation of 123,000 cu. yd. of rock and earth at the Eighth Avenue end of the terminal began in January, 1949; foundation walls were started and an expedient method of prefabricating the formwork and reinforcing (A.S.T.M. A 15) was utilized by the contractors in the efficient construction done under this latter phase of the work. The erection of steel (A.S.T.M. A 7) was started then, and more than 9325 tons were erected, plumbed, and riveted by April, 1950.

The construction of the main terminal will be completed by November of this year. The basic materials utilized cover many fields with which the members of A.S.T.M. are familiar.

The concrete for the piers and foundation walls is controlled by the Inspection Division of the Port Authority at the cement (A.S.T.M. C 175) plant, batching plant, and at the site of construction. In the formation of the structural slabs on other than the Bus Levels, Waylite Aggregates were utilized in order to minimize weight and our tests (A.S.T.M. C 39) have shown that this concrete has developed 1500-psi. compressive strength in 28 days. Red mahogany granite from Minnesota is utilized at the street level for the main architectural scheme with natural brick walls and white marble for architectural trim. Most of the partitions will be concrete block (A.S.T.M. C 129).

Standard electrical equipment will be used throughout the building with transformer rooms and vaults at each street level. It is estimated that 280,000 ft. of steel conduit and 180,000 ft. of wire and cable (A.S.T.M. D 27 and D 752) will be used for distribution of power and 1,200,000 ft. for the lighting and public address systems. Buses will be checked in and out of their berths by means of an automatic detector system controlled from a dispatcher's desk at the bus entrance on 40th Street.

Generally speaking the Bus Terminal uses conventional construction, particular emphasis being placed on durability and ease of maintenance. The paving on which the buses will travel in the basement is reinforced concrete installed in the usual way. On the Suburban Bus Level, which is two floors above Eighth Avenue, a concrete wearing slab has been placed on top of the structural slab and independent of it for ease in replacement when the wear on the paving slab has become excessive. Again on the roof the wearing surface is reinforced concrete placed over asphalt plank (A.S.T.M. D 517) which in turn bears on the structural slab.

Within the ramps connecting the Bus Terminal and the entrance and exit to the Lincoln Tunnel, steel pipe (A.S.T.M. A 120) has been embedded in the structural slabs. During snow storms a petroleum-base material will be circulated through these pipes to provide necessary heat for snow-melting.

It will be noted that, with few exceptions, wherever a standard A.S.T.M. specification is available, this has been used as the basis for the contract specifications. The reason for this is two-fold: (1) to secure the lowest bid price due to "open" type specifications allowing a maximum use of competitive bidding, and (2) to assure a satisfactory end product.

J. M. Kyle

[1] This abstract is of a paper presented by Mr. Kyle at the A.S.T.M. New York District Meeting held in the auditorium of the Port of New York Authority, on May 11, 1950. Mr. Kyle is Chief Engineer of the Port of New York Authority.

Brooklyn-Battery Tunnel[1]

By Ralph Smillie

(An Abstract)

Two weeks from today it is planned to open the Brooklyn-Battery Tunnel to traffic and to add this most recent crossing to the five bridges and one tunnel already owned and operated by the Triborough Bridge and Tunnel Authority. This new tunnel extends under the East River and Buttermilk Channel joining lower Manhattan with the Red Hook Section of Brooklyn. It forms a connecting link between the East and West Side Highways in Manhattan and Hamilton Ave., the Gowanus improvement, and the Brooklyn-Queens Expressway in Brooklyn. Its length of 9117 ft. between portals makes it the longest under-water vehicular crossing in the United States. It is exceeded in length only by the Mersey Tunnel in England. It has cost $83,000,000 from grade point to grade point exclusive of real estate and connecting arteries which have been provided by other agencies.

The tunnel project consists of twin tubes, each carrying two traffic lanes—or a total of four lanes in all.

Of the 9117 ft. between portals, nearly 8000 ft. is cast iron lined tunnel, 31 ft. in outside diameter. The balance, in the vicinity of the portals, is cut-and-cover construction—both steel-bent and reinforced concrete. Of the cast iron lined part of the tunnel, about 5000 ft. is rock tunnel—all in Manhattan schist.

The tunnel interior is quite similar to that of the Lincoln and Queens Midtown Tunnels. Concrete lining inside of the cast iron furnishes support for the roadway and ceiling as well as providing smooth surfaces for air ducts.

While a vehicular tunnel similar to the Brooklyn-Battery Tunnel is primarily a hole in the ground which is excavated either in soft ground with a shield under compressed air or in rock by drilling and blasting in free air, the completed tunnel structure is complex and involves the use of many construction materials.

Whether the material excavated was soft ground as it was in Brooklyn and under Buttermilk Channel or rock as it was under the East River, the primary lining was cast iron. Two weights of cast iron lining were used, designated for convenience as heavy and light. In both cases the rings are 32 in. in width and made up of 14 segments and a key. Heavy rings weigh 22.7 tons and light rings 12½ tons.

The specification requirements for cast iron tunnel lining do not follow any particular A.S.T.M. designation since this class of cast iron has been used for many years, and the requirements have grown with the industry. Machinery scrap (up to 45 per cent of the total melt) is permitted, the balance being pig iron of known quality. Phosphorus is limited to 0.6 per cent and sulfur to 0.12 per cent. A 1¼ in. arbitration bar tested between supports 12 in. apart must sustain a load of at least 3000 lb. and must deflect 0.1 in. before rupture. No tension tests are required. A total of 93,600 tons of cast iron lining was used.

Proper bolting of cast iron tunnel lining is of first importance, not only to secure watertightness but also to prevent opening of the joints with consequent deflection of the ring and upsetting of stress distribution. As the size of bolts is limited, high-strength steel is necessary.

Tunnel bolts are required to be made of carbon-manganese steel containing between 1.2 per cent and 1.5 per cent manganese and between 0.4 and 0.5 per cent carbon. Phosphorus is limited to 0.04 and sulfur to 0.05 per cent. Heat treating is required to give the bolt stock tensile strength of between 110,000 and 130,000 psi. and a yield point of 85,000 to 110,000 psi. For heavy iron, bolts are 1¾ in. in diameter and for light iron, they are 1⅜ in. All threads were rolled.

On the Manhattan end, where most of the tunnel lining was light cast iron erected in previously excavated rock tunnel and where speed as well as uniformity of tightening was highly important, the bolts were tightened mechanically.

The machines used were powered by an Ingersoll-Rand geared air motor to which the wrench proper was connected by a roller chain. By varying the air pressure this wrench could be made to stall at any designed torque. While torque on the nut is not a very accurate measure of bolt tension, it nevertheless gives more uniform values than are obtainable in any other practical way.

The tunnel roadway is a 14-in. concrete slab reinforced with 10-in. I-beams on 21-in. centers transversely with longitudinal bars both above and below the beam flanges to provide longitudinal continuity. The I-beams are required to meet A.S.T.M. standard A 7 and the bars must meet A.S.T.M. A 15; in both cases sulfur is limited to 0.06 per cent and open-hearth steel is a requirement.

Bent steel plate curves are used over an open gutter for the full length of the tunnel. These plates are covered by of A.S.T.M. Standard A 10–39.

The ceiling slab forming the upper air duct is reinforced with mesh covered by A.S.T.M. A 185 and is supported at midpoint by a hanger of "18–8" stainless steel. These hangers are directly in the air stream in the exhaust duct and so must be of a material with a high resistance to corrosion. Stainless steel plates are also used as guide vanes in certain of the duct elbows. These hangers are attached to the tunnel lining by cast steel connecting members conforming to A.S.T.M. A 27–39.

Lead caulking for the cast iron lining is covered by A.S.T.M. B 29 and was formed into wire of a streamline cross-section for ease of insertion in the caulking groove.

The walls and ceilings are faced with a cream-colored glazed tile. The benches are terra cotta, and the pavement is brick so that the interior of the tunnel is almost entirely the product of the ceramic industry.

Water absorption is limited to 2¾ per cent and glaze hardness must be not less than 5 on the Moh scale. Tile must successfully withstand a crazing test in an autoclave at 200 psi.; a thermal shock test (from 230 to 32 F.); and 5 cycles of freezing and thawing.

The ceiling tile were set in place face down on gummed paper laid sticky side up on the ceiling forms. When a form had been completely covered, a dry sand-cement mixture was brushed into the joints of the tile. The surface was then sprayed with water to wet the dry mortar mix. Subsequent steps included setting of wire mesh reinforcing, and pouring of concrete ceiling slab. After the forms had been removed, the gummed paper was washed off with a water jet. Side-wall tile was applied to the

Ralph Smillie

[1] This abstract is of a paper presented by Mr. Smillie at the A.S.T.M. New York District Meeting held in the auditorium of the Port of New York Authority on May 11, 1950. Mr. Smillie is Chief Engineer of the Triborough Bridge and Tunnel Authority.

concrete lining of the tunnel by the float method. Both ceiling and wall tile have projecting buttons on the back surface to form a mechanical bond with the mortar or concrete backing.

Paving brick are the $3\frac{1}{2}$-in. vertical fiber lug type manufactured by the dairing process. A rattler test (A.S.T.M. C 7–42) limits the abrasion loss to 17 per cent and a flexure test (A.S.T.M. C 67–44) limits the modulus of rupture to 2000 psi., average, and 1800 psi., minimum.

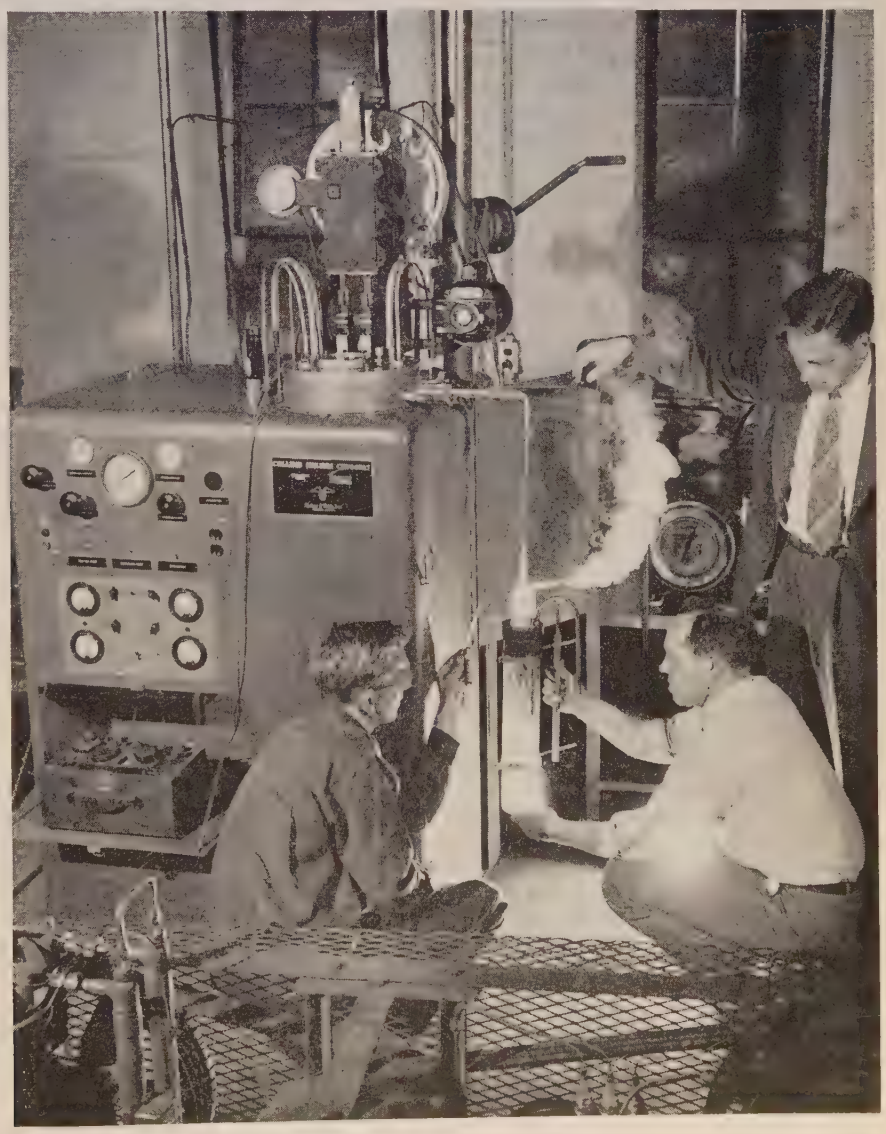
The first paving operation is to spray a prime coat of cut-back asphalt on the concrete slab. Following this a $\frac{3}{4}$-in. thick mastic cushion, composed of cut-back asphalt and sand, is spread with a machine screed. When the brick has been dropped on the mastic cushion they are rolled with a 10-ton roller running on 1-in. thick boards placed longitudinally with the direction of rolling. A parting agent consisting of a solution of calcium chloride and laundry starch is sprayed on top of the brick, after which asphalt joint filler is flushed over the surface. When the joint filler has cooled leather hard, the surplus on top of the pavement is scraped off with scrapers. A somewhat softer joint filler containing mineral flower was used inside the tunnel than that used on the plazas, since the plazas are subjected to high summer temperatures and consequent extrusion of the joint filler.

Two types of insulation were used for electrical conductors. Control, telephone, and switchboard wire is polyvinyl insulated, in which case insulation had to meet the requirements of A.S.T.M. D 734–43 T. Power cable is rubber insulated meeting the requirements of A.S.T.M. D 574–46 T. The sheath is GR-M Polychloroprene meeting A.S.T.M. D 752–46 T.

Principal tunnel operations are governed from a control board in the service building just west of the Brooklyn plaza. The functions controlled from this board have been reduced to a minimum so that a highly trained technician is not required. Carbon monoxide recorders near the bottom of the board give a continuous graphic record of the carbon monoxide content in each of the exhaust duct sections. Above the carbon monoxide recorders, push buttons control the speed of all ventilating fans. At the top of the board are illuminated push buttons showing the position of all tunnel signals and permitting their control from the board as well as from the tunnel.

The four meters on either side of the central clock record the light intensity in the normal zone of each tunnel. This intensity can be varied from the control board to compensate for the normal variables to be found in any lighting system.

The Brooklyn-Battery Tunnel has been built, and will be operated by the Triborough Bridge and Tunnel Authority. Robert Moses, Chairman; George V. McLaughlin and William J. Tracy, Vice-Chairman; George E. Spargo is General Manager and Secretary.



"Transferring Liquid Helium from Collins Helium Cryostat to External Dewar"

An interesting photograph displayed in the General Section of the Seventh A.S.T.M. Photographic Exhibit in Atlantic City, by Charles L. Hanson, Jr., Arthur D. Little, Inc.

List of Technical Committees and Officers

ALTHOUGH complete information will be published in the 1950 Year Book, on the personnel and officers of A.S.T.M. technical committees, this book will not be available until later in the year and hence the list given below showing the chairmen and secretaries of the technical committees will be of interest and service. This year each of the committees has held its election of officers in accordance with the Society regulations which provide for this election in the even-numbered years. An asterisk indicates new officers.

Lost Microscopes

THE Scientific Apparatus Makers Association (S.A.M.A.), Chicago, Ill., has maintained a "File of Stolen Microscopes" as a public service since the Association was formed in 1918.

Owners—professional and amateur scientists, students, and craftsmen—should report first to their police department then to S.A.M.A. immediately a microscope is stolen. Information should be given on make of the instrument, serial number, and other identifying numbers or marks, time and circumstances of theft or loss and any other pertinent information.

S.A.M.A., the trade association of the scientific instrument and laboratory apparatus industry in America, has constant contact with practically all corporations, firms, and individuals who deal in any way with scientific instruments.

Periodically S.A.M.A. sends out to police departments, repair and service shops, pawn shops, etc., a list and details of the most recent thefts.

When S.A.M.A. discovers a stolen microscope it informs the original owner and considers its work done. The owner then may report the discovery to the police for necessary action.

"It is impossible to tell how many stolen microscopes are recovered," Kenneth Andersen, executive vice-president of S.A.M.A., said. "We have no way of knowing how often a police department may find a stolen instrument, check it against the list sent to the department by S.A.M.A., then notify the owner directly. But we do know that that happens often."

Andersen said approximately 100 to 150 instruments are reported stolen each year. Cards remain in the file until S.A.M.A. is notified that the instrument has been discovered. At present there are more than 1000 cards on file, but many of these instruments may have been found and S.A.M.A. not notified, he said. Some cards date back as far as 1935. Most, however, carry dates less than three years old.

Technical Committees, Chairmen, and Secretaries

COMMITTEE	CHAIRMAN	SECRETARY
A-1 on Steel	N. L. Mochel, Westinghouse Electric Corp., Philadelphia 13, Pa.	*J. S. Worth, Bethlehem Steel Co., Inc., Bethlehem, Pa.
A-2 on Wrought Iron	*A. D. Morris, Bayonne Bolt Corp., New York 6, N. Y.	*L. S. Crane, Southern Railway System, Alexandria, Va.
A-3 on Cast Iron	J. S. Vanick, International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.	H. W. Stuart, U. S. Pipe and Foundry Co., Burlington, N. J.
A-5 on Corrosion of Iron and Steel	T. R. Galloway, Consolidated Edison Co. of New York, Inc., New York 3, N. Y.	H. F. Hormann, Consolidated Edison Co. of New York, Inc., 4 Irving Place, New York 3, N. Y.
A-6 on Magnetic Properties	R. L. Sanford, National Bureau of Standards, Washington 25, D. C.	*R. C. Taylor, Western Union Telegraph Co., 60 Hudson St., New York 13, N. Y.
A-7 on Malleable-Iron Castings	W. A. Kennedy, Grinnell Co., Inc., Providence 1, R. I.	James H. Lansing, Malleable Founders' Society, Cleveland 14, Ohio
A-9 on Ferro-Alloys	W. C. Bowden, Jr., Ledoux and Co., Inc., New York 13, N. Y.	G. F. Comstock, The Titanium Alloy Manufacturing Co., Niagara Falls, N. Y.
A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys	Jerome Strauss, Vanadium Corp. of America, New York 17, N. Y.	*M. A. Cordovi, The Babcock & Wilcox Co., 85 Liberty St., New York 6, N. Y.
B-1 on Wires for Electrical Conductors	*H. H. Stout, Jr., Franklin Inst., Benjamin Franklin Parkway, Philadelphia 3, Pa.	A. A. Jones, Anaconda Wire & Cable Co., Hastings-on-Hudson, N. Y.
B-2 on Non-Ferrous Metals and Alloys	Bruce W. Gonser, Battelle Memorial Inst., Columbus 1, Ohio	G. Howard Le Fevre, U. S. Smelting, Refining and Mining Co., New York 5, N. Y.
B-3 on Corrosion of Non-Ferrous Metals and Alloys	K. G. Compton, Bell Telephone Laboratories, Inc., Murray Hill, N. J.	A. W. Tracy, The American Brass Co., Waterbury 20, Conn.
B-4 on Electrical Heating, Resistance, and Related Alloys	S. A. Standing, Tung-Sol Lamp Works, Inc., Bloomfield, N. J.	F. E. Bash, Driver-Harris Co., Harrison, N. J.
B-5 on Copper and Copper Alloys, Cast and Wrought	G. H. Harnden, General Electric Co., Schenectady 5, N. Y.	V. P. Weaver, The American Brass Co., Waterbury 20, Conn.
B-6 on Die-Cast Metals and Alloys	J. R. Townsend, Bell Telephone Laboratories, Inc., Murray Hill, N. J.	G. L. Werley, The New Jersey Zinc Co. (of Pa.), Box 263, Palmerton, Pa.
B-7 on Light Metals and Alloys, Cast and Wrought	I. V. Williams, Bell Telephone Laboratories, Inc., Murray Hill, N. J.	J. J. Bowman, Aluminum Company of America, Pittsburgh 19, Pa.
B-8 on Electrodeposited Metallic Coatings	C. H. Sample, The International Nickel Co., Inc., New York 5, N. Y.	R. B. Saltonstall, The Udylite Corp., Detroit 11, Mich.
B-9 on Metal Powders and Metal Powder Products	W. A. Reich, General Electric Co., Schenectady, N. Y.	Alexander Squire, Westinghouse Electric Corp., East Pittsburgh, Pa.
C-1 on Cement	*R. R. Litehiser, Ohio State Highway and Research Laboratory, O.S.U. Campus, Columbus 10, Ohio	*W. S. Weaver, Canada Cement Co., Ltd., Phillips Sq., Montreal 2, P. Q., Canada
C-2 on Magnesium Oxychloride and Magnesium Oxysulfate Cements	L. S. Wells, National Bureau of Standards, Washington 25, D. C.	G. J. Fink, Oxychloride Cement Assn., Inc., Washington 6, D. C.
C-3 on Chemical Resistant Mortars	*F. O. Anderegg, John B. Pierce Foundation, Raritan, N. J.	*Beaumont Thomas, Stebbins Engineering and Manufacturing Co., Watertown, N. Y.
C-4 on Clay Pipe	J. C. Riedel, Board of Estimates, City of New York, New York, N. Y.	R. G. Scott, Clay Product Assn., Chicago, Ill.

* Indicates new officers.

Technical Committees, Chairmen, and Secretaries

(continued)

C-7 on Lime	W. C. Voss, Massachusetts Inst. of Technology, Cambridge, Mass.	Robert S. Boynton, National Lime Assn., Washington 5, D. C.
C-8 on Refractories	R. B. Sosman, Rutgers University, New Brunswick, N. J.	W. R. Kerr, Armstrong Cork Co., Beaver Falls, Pa.
C-9 on Concrete and Concrete Aggregates	Kenneth B. Woods, Purdue University, West Lafayette, Ind.	Stanton Walker, National Sand and Gravel Assn., Washington 4, D. C.
C-11 on Gypsum	L. S. Wells, National Bureau of Standards, Washington 25, D. C.	*L. H. Yeager, Gypsum Assn., 530 Opera Bldg., Chicago 6, Ill.
C-12 on Mortars for Unit Masonry	*J. M. Hardesty, Bell Telephone Laboratories, Inc., Murray Hill, N. J.	*Harry C. Plummer, Structural Clay Products Inst., Washington 6, D. C.
C-13 on Concrete Pipe	W. W. Horner, Horner & Shifrin, St. Louis 3, Mo.	H. F. Peckworth, American Concrete Pipe Assn., Chicago 1, Ill.
C-14 on Glass and Glass Products	*L. G. Ghering, Preston Laboratories, Butler, Pa.	F. V. Tooley, University of Illinois, Urbana, Ill.
C-15 on Manufactured Masonry Units	J. W. Whittemore, Virginia Polytechnic Inst., Blacksburg, Va.	*M. H. Allen, Structural Clay Products Inst., Washington 6, D. C.
C-16 on Thermal Insulating Materials	*E. R. Queer, The Pennsylvania State College, State College, Pa.	*R. P. Sturgis, Socony-Vacuum Oil Co., Inc., Paulsboro, N. J.
C-17 on Asbestos-Cement Products	H. R. Snoke, National Bureau of Standards, Washington 25, D. C.	C. C. Kelsey, Asbestos Cement Products Assn., New York 22, N. Y.
C-18 on Natural Building Stones	L. W. Currier, U. S. Geological Survey, Dept. of Interior, Washington 25, D. C.	F. S. Eaton, Research and Design Inst., Inc., New Haven 10, Conn.
C-19 on Structural Sandwich Constructions	A. G. H. Dietz, Massachusetts Inst. of Technology, Cambridge 39, Mass.	E. C. Hartmann, Aluminum Research Laboratories, Aluminum Company of America, New Kensington, Pa.
C-20 on Acoustical Materials	*H. A. Leedy, Armour Research Foundation, Chicago 16, Ill.	*H. J. Sabine, The Celotex Corp., Chicago 3, Ill.
C-21 on Ceramic Whiteware	J. H. Koenig, Rutgers University, New Brunswick, N. J.	R. F. Geller, National Bureau of Standards, Washington 25, D. C.
C-22 on Porcelain Enamel	*W. N. Harrison, National Bureau of Standards, Washington 25, D. C.	*G. H. Spencer-Strong, Pemco Corp., 5601 Eastern Ave., Baltimore 24, Md.
D-1 on Paint, Varnish, Lacquer, and Related Products	W. T. Pearce, Bala-Cynwyd, Pa.	C. H. Rose, National Lead Co., Washington 6, D. C.
D-2 on Petroleum Products and Lubricants	*O. L. Maag, The Timken Roller-Bearing Co., Canton 6, Ohio	W. T. Gunn, American Petroleum Inst., New York 20, N. Y.
D-3 on Gaseous Fuels	A. W. Gauger, The Pennsylvania State College, State College, Pa.	K. R. Knapp, American Gas Assn., Cleveland 3, Ohio
D-4 on Road and Paving Materials	*C. E. Proudley, North Carolina State Highway and Public Works Comm., Raleigh, N. C.	B. A. Anderton, The Barrett Div., Allied Chemical and Dye Corp., Edgewater, N. J.
D-5 on Coal and Coke	W. A. Selvig, U. S. Bureau of Mines, Pittsburgh 13, Pa.	C. H. Sawyer, Eastern Gas and Fuel Associates, Pittsburgh 12, Pa.
D-6 on Paper and Paper Products	W. R. Willets, Titanium Pigment Corp., New York 13, N. Y.	*R. H. Carter, General Electric Co., Schenectady 5, N. Y.
D-7 on Wood	L. J. Markwardt, U. S. Forest Products Laboratory, Madison 5, Wis.	

* Indicates new officers.

Effect of Fuel Immersion on Plastics

CHANGES in weight and in the dimensional and flexural properties of laminated plastics immersed in three hydrocarbon liquids have been measured at the National Bureau of Standards as a means of evaluating the relative resistance of the laminates to different fuels. Constituting one phase of a continuing program on the properties of laminates for a wide variety of aircraft applications, the tests were designed to provide data needed in the preparation of specifications for those plastics found suitable for use as auxiliary (droppable) fuel tanks, radomes, instrument panels, and containers. The study[1], conducted under the sponsorship of the National Advisory Committee for Aeronautics at the Bureau's organic plastics laboratory, involved the determination of the effects on representative laminated plastics of cyclic and continuous immersion in three fuels: heptane (an aliphatic hydrocarbon), toluene (an aromatic hydrocarbon), and SR-6, a representative aircraft test fuel composed of blended aliphatic and aromatic hydrocarbons.

". . . . There are four mechanisms by which the sense of smell can be prevented from detecting an odor," William L. Kubie says. "They are fatigue, anesthesia, neutralization, and masking."

Fatigue is the fading of the intensity with which an odor is detected, although the strength of the odor remains the same. Anesthesis is the complete blocking of the sense of smell toward all odors. Neutralization is the combination of two odors that results in less odor stimulation than that from either odor alone. Masking obliterates one odor by superimposing another on it. It is the masking effect that makes "strike anywhere" matches useful as a deodorant.

[1] For further technical details see forthcoming N.A.C.A. Technical Note, Effect of Fuel-immersion on Laminated Plastics, by William A. Crouse, Margie Carickhoff, and Margaret A. Fisher.

Spectrographic Standard Samples Issued by NBS

THE National Bureau of Standards has added 12 spectrographic standards to its list of analyzed standard samples. Two of the standards are steel and ten are metallic tin.

A medium-manganese steel is available in two sizes as Standards 405A and 805A with a provisional certificate of analysis for the following constituents: manganese 1.90 per cent, silicon 0.27 per cent, nickel 0.065 per cent, chromium 0.037 per cent, molybdenum 0.005 per cent, and aluminum 0.058 per cent. Standard 405A is a rod 4 in. long and $\frac{7}{32}$ in. in diameter and Standard 805A is a rod 2 in. long and $\frac{1}{2}$ in. in diameter. The price of each standard is $5 (prepaid).

The tin standards are five alloys, each available in two sizes with a provisional certificate of analysis for ten constituents. Standards 431 to 435 are rods 4 in. long and $\frac{1}{4}$ in. in diameter, priced at $8 ea. (prepaid). Standards 831 to 835 are rods 2 in. long and $\frac{1}{2}$ in. in diameter, priced at $14 ea. (prepaid).

Technical Committees, Chairmen, and Secretaries

(continued)

D-8 on Bituminous Waterproofing and Roofing Materials	*A. J. Steiner, Underwriters' Laboratories, Inc., Chicago 11, Ill.	*G. W. Robbins, The Texas Company, New York 17, N. Y.
D-9 on Electrical Insulating Materials	*A. H. Scott, National Bureau of Standards, Washington 25, D. C.	*M. Guarnier, General Electric Co., Schenectady 5, N. Y.
D-10 on Shipping Containers	T. A. Carlson, U. S. Forest Products Laboratory, Madison, Wis.	E. R. Stivers, Package Research Laboratory, Rockaway, N. J.
D-11 on Rubber and Rubber-Like Materials	Simon Collier, Johns-Manville Corp., 22 E. 40th St., New York 16, N. Y.	Arthur W. Carpenter, The B. F. Goodrich Co., Akron 11, Ohio
D-12 on Soaps and Other Detergents	*J. C. Harris, Monsanto Chemical Co., Dayton 7, Ohio	*H. R. Suter, Wyandotte Chemicals Corp., Wyandotte, Mich.
D-13 on Textile Materials	*W. D. Appel, National Bureau of Standards, Washington 25, D. C.	W. H. Whitcomb, Cranston 10, R. I.
D-14 on Adhesives	Frank W. Reinhart, National Bureau of Standards, Washington 25, D. C.	*L. M. Perry, Nashua Gummed and Coated Paper Co., Nashua, N. H.
D-15 on Engine Antifreezes	H. R. Wolf, General Motors Corp., Detroit 2, Mich.	*R. J. Harker, Commercial Solvents Corp., Terre Haute, Ind.
D-16 on Industrial Aromatic Hydrocarbons	D. F. Gould, The Borden Co., Philadelphia 24, Pa.	R. B. Greene, The Barrett Div., Allied Chemical and Dye Corp., Philadelphia 37, Pa.
D-17 on Naval Stores	V. E. Grotlisch, Production and Marketing Administration, Dept. of Agriculture, Washington 25, D. C.	W. A. Kirklin, Hercules Powder Co., Wilmington 99, Del.
D-18 on Soils for Engineering Purposes	E. J. Kilcawley, Rensselaer Polytechnic Inst., Troy, N. Y.	*W. G. Holtz, U. S. Bureau of Reclamation, Denver, Colo.
D-19 on Industrial Water	Max Hecht, 25 Valley Rd., Apt. 9, Drexelbrook, Drexel Hill, Pa.	*Robt. T. Sheen, Milton Roy Co., Philadelphia 18, Pa.
D-20 on Plastics	G. M. Kline, National Bureau of Standards, Washington 25, D. C.	B. L. Lewis, Tinius Olsen Testing Machine Co., Willow Grove, Pa.
D-21 on Wax Polishes and Related Material	*J. I. Hoffman, National Bureau of Standards, Washington 25, D. C. (temp.)	*B. S. Johnson, Franklin Research Co., Philadelphia 31, Pa. (temp.)

E-1 on Methods of Testing	J. R. Townsend, Bell Telephone Laboratories, Inc., Murray Hill, N. J.	P. J. Smith, American Society for Testing Materials, Philadelphia, Pa.
E-2 on Emission Spectroscopy	B. F. Scribner, National Bureau of Standards, Washington 25, D. C.	*J. H. Coulliette, University of Chattanooga, Chattanooga 3, Tenn.
E-3 on Chemical Analysis of Metals	*J. W. Stillman, E. I. du Pont de Nemours and Co., Inc., Wilmington 98, Del.	*H. Kirtchik, General Electric Co., West Lynn, Mass.
E-4 on Metallography	L. L. Wyman, General Electric Co., Schenectady 5, N. Y.	Mary Norton, Watertown Arsenal, Watertown 72, Mass.
E-5 on Fire Tests of Materials and Construction	A. L. Brown, Associated Factory Mutual Fire Insurance Cos., Boston 10, Mass.	Hugh M. Robinson, Underwriters' Laboratories, Inc., Chicago 11, Ill.
E-6 on Methods of Testing Building Constructions	J. A. Liska, U. S. Forest Products Laboratory, Madison 5, Wis.	J. H. Courtney, American Standards Assn., Inc., c/o National Bureau of Standards, Washington 25, D. C.
E-7 on Non-Destructive Testing	J. H. Bly, Pratt & Whitney Aircraft, East Hartford, Conn.	D. T. O'Connor, Naval Ordnance Lab., White Oak, Silver Spring 19, Md.

* Indicates new officers.

Low-Temperature Potentialities of the Silicone Rubbers

Based primarily on measurements[1] of the second-order transition temperature of the silicone rubbers by C. E. Weir, W. H. Leser, and L. A. Wood of the National Bureau of Standards, it appears that the silicone rubbers, developed especially for high-temperature applications, have better potentialities for use at extremely low temperatures than any synthetic or natural rubber studied thus far.

In recent years a need has also arisen for a type of rubber capable of withstanding low temperatures without loss of its characteristic rubber-like properties. Tires, belting, or other articles of ordinary rubber lose their elasticity around −60 F., presenting many difficulties in connection with the operation of motor vehicles and machinery in the arctic or of airplanes at great height. To learn more about the possibilities of using the silicones for such low-temperature applications, the Bureau determined the lower limit of the temperature range in which they retain their characteristic elasticity by locating the second-order transition temperature, a temperature at which a marked change in the slope of the length-temperature curve occurs. In practice a rubber becomes useless for applications requiring long-range elasticity at temperatures somewhat higher than the transition temperature, the exact amount of the difference depending on the particular application. Thus in natural rubber the second-order transition temperature is at −94 F., but the rubber is seldom useful below about −67 F.

Small slabs of rubber were placed between two quartz interferometer plates. Then, as the temperature of an interferometer was changed, the rubber slabs contracted or expanded, changing the distance between the plates and causing the interference fringes to the eyepiece to move relative to a fixed point of reference. The temperature of the specimens was recorded, and the number of fringes passing the reference point was counted as the temperature was varied slowly from −321 F., the boiling point of liquid nitrogen, to 212 F.

The silicone rubbers studied were all of commercial origin; two being especially designed for low-temperature applications.

One of the two low-temperature silicone rubbers was outstanding in that its expansion curve was essentially linear from 212 F. until the second-order transition temperature of approximately −189 F. was reached. Below this temperature a much lower coefficient of thermal expansion, more nearly like that of a rigid solid, was observed. This particular silicone rubber which exhibited no first-order transition (a recrystallization takes place) should have good possibilities for use at temperatures as low as −148 F.

[1] For further technical details, see "Crystallization and Second-Order Transitions in Silicone Rubbers," by C. E. Weir, W. H. Leser, and L. A. Wood, *Journal Research*, National Bureau of Standards, Vol. 44, p. 367, 1950 (*RP*2084).

Technical Committees, Chairmen, and Secretaries

(concluded)

E-8 on Nomenclature and Definitions	P. V. Faragher, Aluminum Co. of America, Pittsburgh 19, Pa.	P. J. Smith, American Society for Testing Materials, Philadelphia, Pa. (*ex-officio*)
E-9 on Fatigue	R. E. Peterson, Westinghouse Electric Corp., East Pittsburgh, Pa.	O. J. Horger, The Timken Roller Bearing Co., Canton 6, Ohio
E-11 on Quality Control of Materials	H. F. Dodge, Bell Telephone Laboratories, Inc., New York 14, N. Y.	O. P. Beckwith, Alexander Smith and Sons Carpet Co., Yonkers 1, N. Y.
E-12 on Appearance	M. Rea Paul, Frederic H. Rahr, Inc., New York 22, N. Y.	Daniel Smith, Interchemical Corp., New York 19, N. Y.
E-13 on Absorption Spectroscopy	W. R. Brode, National Bureau of Standards, Washington 25, D. C.	W. S. Young, The Atlantic Refining Co., Philadelphia 1, Pa.

BOOK REVIEWS...

Exudation and Allied Reactions Between Bitumens

ONE of the latest textbooks prepared, covering the very difficult field of chemical composition and colloidal structure of bitumens, is that by G. L. Oliensis, Director of Research, Lloyd A. Fry Roofing Co. A review of the results of 15 years of study and research into contact reactions between bitumens of differing types is given. Four new test methods for the detection and control of these reactions and the proper utilization is also described, together with the presentation of a new theory on the internal structure of bitumens that account for these reactions. The four new tests described are exudation, insudation, transudation, and sudative-flow tests. This work should be of interest to the oil, asphalt, and coal-tar refiner, the roofing manufacturer, bituminous technologist, and highway engineers and to the chemist and bituminous laboratory worker. This book can be obtained from the Chicago Bureau of Bituminous Technology, P. O. Box 31, Forest Park, Ill., for the price of $5.50 in cloth and $4.50 in heavy paper covers.

Properties of Metals at Elevated Temperatures

THIS new book covering the properties of metals at elevated temperatures is another in the Metallurgy and Metallurgical Engineering Series issued by McGraw-Hill with Dr. R. F. Mehl as Consulting Editor. The author, Dr. G. V. Smith, Research Laboratory, U. S. Steel Corp., is an intensive worker in this field and his book should be of much interest to all those interested in this subject which steadily grows to be of increasing significance.

Two other leading men, Dr. Mehl, Carnegie Institute of Technology, and Dr. R. F. Miller, Carnegie-Illinois Steel Corp., reviewed the book in detail, and Dr. Miller has included a short foreword and prepared an interesting appendix covering "superalloys" with tables of chemical compositions and a list of some 60 pertinent references. Speaking of references, the main body of the book has a reference section involving 488 reference citations including many from A.S.T.M. publications.

The initial chapters of the book are of a fundamental character, and deal from a metallurgical point of view with the nature of plastic deformation and fracture of metals—first at ordinary temperature and then at elevated temperature. Next the test apparatus and test procedures employed in evaluating metals for service at elevated temperatures are described. This is followed by chapters which summarize available knowledge on the effects of such variables as chemical composition, manufacturing practice, and heat treatment. A separate chapter is devoted to the question of scaling of metals and to the nature of the changes in microstructure which may be expected to occur during service. A final chapter deals with the problem of design for service at elevated temperatures, particularly with the choice of working stress.

Copies of this 410-page book, 6 by 9 in., can be procured from the publishers, 330 W. 42nd St., New York, N. Y., or book dealers, at $7 per copy.

Recommended Practices for Resistance Welding

A NEW, revised, and enlarged (60 pages) edition of the *Recommended Practices for Resistance Welding* has just been published by the Am. Welding Soc. This new edition represents a modification and expansion of the standard originally issued in tentative form in 1946. Included are welding schedules for spot and seam welding mild and medium carbon steels, low-alloy steels, stainless steels, nickel, monel, Inconel, and magnesium alloys.

Recommended practices for projection welding cover low-carbon and stainless steels. Flash welding data are provided for low- and medium-forging strength steels.

The section on methods of testing resistance welds includes the new peel test and an expanded discussion of the control of resistance weld quality by statistical methods. Other methods of test for which the standard specimen, method of testing, and evaluation of results are given include the tension-shear test, cross and U-tension tests, shear and drop impact tests, fatigue test, and twist test. The standard pillow test for seam welds is also described.

Copies may be obtained at $1 each from the Am. Welding Soc., 33 W. 39th St., New York, N. Y.

Acceptance Sampling

THE printed papers and discussion presented in this volume form a symposium on Acceptance Sampling, which was held by the American Statistical Association after the close of hostilities in the recent War. The subject was of special interest, then and now, because of the great developments just previous to and during the war.

The natural division of the subject into methods for dealing with attributes (categories) and methods dealing with variables (measurements expressed quantitatively) was followed in the session and is followed here.

While this material should be of highest interest to those concerned in acceptance sampling, there will be much in the way of ideas, and even techniques, which will be valuable to practitioners and users of statistics over a wide field. One example is the recent application (by Greenhouse and Mantel) of the same pattern to the assessment of diagnostic tests for a specific disease.

Specifically, the table of contents lists the following papers and discussions and their authors:

Acceptance Sampling by Attributes:

- Developments prior to 1941...Paul Peach
- Wartime Developments.....E. G. Olds
- Prepared Discussion...W. Bartky, H. R. Bellinson, and D. H. Schwartz
- Open Discussion...W. Bartky, H. R. Bellinson, A. Blake, Irving Burr, J. H. Curtiss, Besse Day, W. H. Gore, A. S. Marthens, E. C. Molina, F. Mosteller, P. Peach, D. H. Schwartz, L. W. Shaw, L. E. Simon, C. C. Van Vechten, W. Allen Wallis, and A. E. R. Westman

Acceptance Sampling by Variables:

- Lot Quality Measured by Average or Variability.....John H. Curtiss
- Lot Quality Measured by Proportion Defective.....W. Allen Wallis
- Prepared Discussion....Kenneth J. Arnold, J. F. Daly, A. M. Mood, E. M. Schrock, and A. E. R. Westman
- Open Discussion...A. Blake, Burton H.

Camp, W. G. Cochran, J. H. Curtiss, Besse Day, W. H. Gore, H. Hotelling, A. S. Marthens, F. Mosteller, H. Rubin, D. H. Schwartz, L. Shaw, J. H. Smith, J. W. Tukey, W. Allen Wallis, A. E. R. Westman, and C. P. Winsor

Chairman's Closure.....J. W. Tukey

In the words of J. W. Tukey, symposium chairman, the three cornerstones on which statistics have been built—"empirical examples, mathematical examples, and scientific method" are strongly evident in all of the symposium's papers and discussions.

Further information about Acceptance Sampling can be obtained by writing to the American Statistical Association, Washington, D. C.

Inspection Methods

THE new Industrial Inspection Methods, by Leno C. Michelon, Purdue University, has been rather completely revised and reset. Half again as long as the original text, it presents precision measurement as it is today—its growth in techniques, standardization, new devices, and statistical methods.

Here, then, is a comprehensive and scientific presentation of the principles and current practices in industrial inspection work, covering most major aspects of precision measurements.

The major divisions of the work are concerned with basic concepts, dimensional control, testing for physical and mechanical properties, surface inspection, and inspection organization and personnel. The various precision and nonprecision tools used in inspection work are described fully and their correct use illustrated. Rules, micrometers, verniers, gages, dial indicators, comparators, optical measuring devices, automatic gages, etc., are fully covered. Extended treatment is given to statistical quality control methods, modern destructive and nondestructive tests for physical and mechanical properties, modern techniques in surface measurement, and other similar topics.

All pertinent tables, 450 line cuts and half tones, and charts are included, as well as a complete list of bibliographical and visual aids. Problems and questions for study are also provided for each chapter of the 568-page test. Price is $6; Harper Bros. are the publishers.

Statistical Analysis

IN THIS book on elementary statistical analysis by S. S. Wilks, an effort has been made throughout to emphasize the role played in statistical analysis by a sample of measurements and a population from which the sample is supposed to have arisen. Only three chapters are devoted to elementary descriptive statistics of a sample of measurements. In these three chapters the idea of a population is presented on a purely intuitive basis. Probability concepts are then introduced. This makes it possible to use these basic concepts at an early stage in dealing more critically with the idea of a population and sampling from a population. Considerable attention is given to the application of sampling principles to the simpler problems of statistical inference such as determining confidence limits of population means and difference of means, making elementary significance tests, testing for randomness, etc. No attempt has been made here to go into analysis of variance and more sophisticated problems of statistical inference, but an elementary treatment of analysis of pairs of measurements including least squares methods is presented. Special effort also has been made to keep the mathematics elementary and to state specifically at which points the mathematics is too advanced to present.

Price: $2.50, 284 pages including index; Princeton University Press, Princeton, N. J.

War Emergency Issues 37–46, 1940 Proceedings of The Institution of Mechanical Engineers

THESE War Emergency Issues 37–46, comprising Vol. 159 of the Proceedings of The Institution of Mechanical Engineers (London), contain papers of a specialized character made available only to libraries and to members of the Institution who apply for them.

Among the papers included in the volume are the following:

"The Tensile Yield Strength of Certain Steels under Suddenly Applied Loads," F. V. Warnock and J. B. Brennan.

"The Dynamic Yield Strength of Steel at an Intermediate Rate of Loading," A. F. C. Brown and R. Edmonds.

"The Criterion of 'Yield' of Gun Steels," J. L. M. Morrison.

"A Comparison of Some Carbon Molybdenum Steels on the Basis of Various Creep Limits," A. E. Johnson and H. J. Tapsell.

"Factors Influencing the Weldability of High Tensile Alloy Steels, and a New Weld Cracking Test," P. L. J. Leder.

"Large Scale Torsional Fatigue Testing of Marine Shafting," S. F. Dorey.

The Proceedings of The Institution of Mechanical Engineers are published by the Institution at Storey's Gate, St. James Park, London, S.W. 1, England.

Properties of All Refrigerants

A HANDY booklet, "Refrigerant Tables, Charts and Characteristics," containing the complete compilation of refrigerant properties in chart and table form has been issued by the American Society of Refrigerating Engineers, 40 W. 40th St., New York City.

This 93-page booklet is unique in that it contains in one volume tables of properties, pressure-enthalpy diagrams, and Mollier charts for all commonly used refrigerants.

Copies may be obtained from A.S.R.E. Headquarters, Am. Soc. Refrigerating, 40 W. 40th St., New York 18, N. Y., at $1.50 the copy, bound in paper, and $2 the copy, bound in cloth.

Perry's Chemical Engineers' Handbook—New 3rd Edition

PREPARED by a staff of specialists and with John H. Perry, Technical Investigator, E. I. du Pont de Nemours and Co., as Editor, the new 3rd edition of Perry's "Chemical Engineers' Handbook" provides a revision of this standard chemical engineering reference work. It includes a fresh and comprehensive coverage of both standard and recently compiled facts, figures, and methods applicable to chemical engineering and its related fields.

An authoritative group of more than 140 recognized specialists have contributed detailed explanations of new developments in many branches of the industry to bring the Handbook up to date on approved technical data, procedures, and equipment. Important information, previously restricted to "classified" listing, is listed for the first time.

A total of 1884 enlarged 2-column pages (7½ by 9⅞ in.) is included in the new Handbook, and 30 complete sections are presented to give engineers and others engaged in the industry a full coverage of essential processes, equipment, and materials.

In addition to some expanded and wholly or partially revised chapters and major sections, the new edition features several entirely new sections. These provide information pertaining to furnaces and kilns, size enlargement, general theory of diffusional operations, distillation processes, and dialysis.

Other improvements included in the 3rd edition are (1) an increased coverage and new treatment of low-temperature processes, methods of mechanical separations, and sublimation; (2) revised material on flow of fluids, heat transmission, solvent extraction, mixing, adsorption, physical and chemical data, and physical and chemical principles; (3) new presentation of humidification, dehumidification, spray ponds and cooling towers, mathematics, mathematical tables and weights and measures; (4) further revision of material on fuels, electrochemistry, electricity and electrical engineering, materials of construction, mechanical separations, safety and fire protection, accounting and cost finding; (5) expanded material on size reduction, power generation, process control, high-pressure technique, plant location, gas absorption, and movement and storage of materials.

Published by the McGraw-Hill Co., New York City, the new Handbook is $15.

The Society Appoints . . .

Announcement is made of the following appointments of Society representatives

T. S. Fuller, General Electric Co.; W. H. Fulweiler, Consulting Chemist; H. F. Moore, University of Illinois; and J. R. Townsend, Bell Telephone Laboratories, Inc., reappointed for a term of three years on Committee E-1 on Methods of Testing.

A. W. Gauger, Pennsylvania State College, and Simon Collier, Johns-Manville Corp., as members of the Advisory Committee of Committee E-8 on Nomenclature and Definitions for a term of three years, succeeding C. A. Marlies and J. L. Miner, deceased.

William A. Oliver, University of Illinois, as alternate to L. J. Markwardt, U. S. Forest Products Laboratory, on A.S.A. Sectional Committee O 5 on Specifications for Wood Poles, replacing Hermann von Schrenk.

G. H. Harnden, General Electric Co., on A.S.A. Miscellaneous Projects Correlating Committee.

H. K. Nason, Monsanto Chemical Co., on A.S.A. Chemical Industry Correlating Committee.

M. N. Clair, The Thompson and Lichtner Co., Inc., reappointed to A.S.A. Building Code Correlating Committee.

Gordon Thompson, Electrical Testing Laboratories, Inc., on A.S.A. Sectional Committee C-8 on Specifications for Insulated Wires and Cables (Other than Telephone and Telegraph), replacing F. M. Farmer.

I. V. Williams, Bell Telephone Laboratories, Inc., on S.A.E. Non-Ferrous Metals Division, succeeding C. S. Cole, deceased.

W. T. Pearce, Consultant on Organic Coatings, as representative of Committee D-1 on the Inter-Society Color Council on Color Transparent Materials.

F. W. Reinhart, National Bureau of Standards, and R. C. Platow, Bell Telephone Laboratories, Inc., as representatives of Committee D-14 on Adhesives, on the Advisory Committee on Corrosion.

The following appointments have been made to various administrative committees of the Society; all being reappointments, except in the cases of Messrs. Zinzow and Ellis, which are new:

D. E. Parsons, National Bureau of Standards, and W. A. Zinzow, Union Carbide and Carbon Corp., on the *Standards Committee;* P. D. Brossman, E. I. du Pont de Nemours & Co., Inc., and O. W. Ellis, Ontario Research Foundation, *Research;* R. C. Adams, U. S. Naval Engineering Experiment Station; A. Melshimer, American Cyanamid Co., and C. H. Sample, The International Nickel Co., *Papers and Publications;* Jules Labarthe, Mellon Institute of Industrial Research; H. H. Morgan, Robert W. Hunt Co.; and P. S. Olmstead, Bell Telephone Laboratories, Inc., *Ultimate Consumer Goods;* E. L. Hollady, U. S. Department of the Army; R. E. Peterson Westinghouse Electric Corp.; and L. B. Jones, Consulting Engineer, *Simulated Service Testing;* T. P. Dresser, Jr., Abbot A. Hanks, Inc., and F. G. Steinebach, Editor, *The Foundry, District Activities.*

A. J. Eickhoff, National Lead Co., as Society representative on the Steel Structures Paint Research Council.

O. L. Maag, Timken Roller Bearing Co., on A.S.A. Sectional Committee Z 11 on Petroleum Products and Lubricants, replacing C. Dantsizen, resigned.

Cyril M. Harris, Bell Telephone Laboratories, Inc., representing Committee D-20 on A.S.A. Sectional Committee Z 24 on Acoustical Measurements, to replace R. E. Hess, Technical Secretary, A.S.T.M.

R. E. Hess, Technical Secretary, A.S.T.M., as interim A.S.T.M. representative on the Research Council on Graphic Arts Industry.

The following appointments have been made to Award Committees:

Dudley Medal Committee: E. E. Thum, Editor, *Metal Progress,* and C. E. Proudley, North Carolina State Highway and Public Works Commission, to serve with E. F. Kelley, Bureau of Public Roads; G. M. Kline, National Bureau of Standards; J. M. Lessells, Massachusetts Institute of Technology; and H. L. Maxwell, E. I. du Pont de Nemours & Co., with Mr. Maxwell serving as chairman.

Sam Tour Award Committee: R. B. Mears, Carnegie-Illinois Steel Corp., to serve with Russell Franks, Union Carbide & Carbon Corp., and A. W. Tracy, The American Brass Co., with Mr. Tracy serving as chairman.

Richard L. Templin Award Committee: T. Smith Taylor, United States Testing Co., Inc., to serve with T. J. Dolan, University of Illinois, and J. R. Dwyer, National Bureau of Standards, with Professor Dolan serving as chairman.

Townsend Honored

A.S.T.M. Past-President John R. Townsend, Materials Engineer, Bell Telephone Laboratories, was among those who were signally honored recently by the American Standards Association through the presentation of Honorary Certificates for outstanding service on the Standards Council of the A.S.A. Mr. Townsend is one of the two current A.S.T.M. official representatives on the Council, and not only in this capacity but in many others he has done a great deal to promote the work of A.S.A. Certain other A.S.T.M. members and committee members also received these Certificates. A.S.T.M. Past-President F. M. Farmer, who for many years represented A.S.T.M. on the Council, accepted the awards for the other Council members.

50-Million-volt Betatron Laboratory

A 50-million-volt betatron, designed and constructed by the General Electric Co., has been installed in the National Bureau of Standards' new betatron laboratory, extending the Bureau's high-energy research into the region from 2 to 50 million electron volts.

In the past, the Bureau has established standards for protection against low-energy X-rays, and the new betatron research program will fill the need for standards of protection in the higher regions now available to medicine. The much deeper penetration of high-energy X-rays requires entirely new scientific standards for full exploitation of these sources of radiation while maintaining adequate protection.

Standards of protection have an economic aspect. Today, the exact wall thicknesses and best structural materials are not known for high-energy X-rays. In order to be on the safe side, high-energy installations are overprotected, with excessively thick walls and barriers which add greatly to the cost. In many installations the cost of protective walls and barriers exceeds that of the X-ray or betatron equipment itself. Accurate recommendations for barrier thicknesses in the high-energy field should produce large savings.

Also, with radiations from the new betatron, a small flaw can be detected far beneath the surface of a metal casting, permitting the quick examination of a much greater depth than has been possible with low-energy radiation.

Calendar of Society Meetings

Electron Microscope Society of America—Annual Meeting, September 14–16, Hotel Statler, Detroit, Mich.

5th National Instrument Conference & Exhibit—September 18–22, Memorial Auditorium, Buffalo, N. Y.

American Institute of Mechanical Engineers—Fall Meeting, September 24–October 1, Columbus, Ohio.

American Association of Textile Chemists & Colorists—September 28–30, The Wentworth, Portsmouth, N. H.

American Society of Civil Engineers—Fall Meeting, October 11–13, Chicago, Ill.

American Chemical Society, Rubber Div., —International Rubber Meeting, October 11–13, Hotel Cleveland, Ohio.

Electrochemical Society, Inc.—October 11–14, Hotel Statler, Buffalo, N. Y.

Engineers' Society of Western Pennsylvania—Eleventh Annual Water Conference, October 16–18, Hotel William Penn, Pittsburgh, Pa.

Society of Plastics Industry—Annual National Conference, October 18–20, New Ocean House, Swampscott, Mass.

32nd National Metal Congress & Exposition—October 23–27, Chicago's Amphitheatre, Chicago, Ill.

Association of Consulting Chemists & Engineers, Inc.—Annual Meeting, October 24, Shelburne Hotel, New York, N. Y.

PERSONALS...

News items concerning the activities of our members will be welcomed for inclusion in this column

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NOTE—*These "Personals" are arranged in order of alphabetical sequence of the names. Frequently two or more members may be referred to in the same note, in which case the first one named is used as a key letter. It is believed that this arrangement will facilitate reference to the news about members.*

Guy A. Baker has been appointed Vice-President in Charge of Manufacturing of the Duriron Co., Inc., Dayton, Ohio. For several years he has been Assistant to the President and Secretary of the company, and previously had been Manager of the company's Alloy Castings Sales. Associated with Duriron for the past twenty years, Mr. Baker has been active in metallurgical research and development.

Bani R. Banerjee, formerly of the faculty of the Department of Metallurgical Engineering, Illinois Institute of Technology, received the degree of Doctor of Engineering from Yale University in June, and is now Research Engineer, Research Engineering Division, Standard Oil Co., Chicago.

Cecil J. Bier has accepted a position as Metallurgist, Radio Cores, Inc., Oak Lawn, Ill. He was previously Chief Engineer, Powmetco, Inc., East Port Chester, Conn.

Robert A. Bittenbender, formerly Technical Engineer, Jackson & Moreland, Boston, Mass., is now Mechanical Engineer with Sylvania Electric Products, Inc., of the same city.

Miles Nelson Clair has been elected President of The Thompson & Lichtner Co., Inc., Brookline, Mass. He was formerly Vice-President and Treasurer.

John C. Coonley is now Manager, Valve Div., American Car & Foundry Co., Detroit, Mich. He was previously associated with The Heald Machine Co., Worcester, Mass., as Assistant Works Manager.

Donald Thomas Davidson is now Research Associate Professor of Civil Engineering at Iowa State College, Ames.

Harry M. Dewey, formerly with Civil Engineering Service, Inc., Portland, Ore., is now Director, Div. of Engineering, Agriculture and Forestry, Idaho State College, Pocatello.

John H. Dillon, Director of Research, Textile Research Institute, Inc., Princeton, N. J., has been given an honorary degree of Doctor of Science by Ripon College.

B. T. du Pont, General Manager, Plastics Metals Div. of National Radiator Co., Johnstown, Pa., has been re-elected President of the Metal Powder Assn. for the coming year.

Clarence R. Eckert is now Director of Research with The Ruberoid Co., South Bound Brook, N. J.

Richard C. Elstner, formerly Instructor in Materials, University of Hawaii, Honolulu, is now engaged in student research work at the University of Illinois, Urbana.

Harry David Foster has been appointed Fire Prevention Engineer, New York State Building Code Commission, with headquarters in New York City. He was previously associated with the National Bureau of Standards, Washington, D. C., in a similar capacity.

N. J. Gothard, formerly Assistant Chief Chemist, has been named Chief Chemist, Sinclair Refining Co., Harvey, Ill.

George H. Hansen has accepted a position as Chemist with Brighton Terminal, Ltd., Trinidad, B. W. I. He was previously associated with The Trinidad Lake Asphalt Operating Co., Ltd., in a similar capacity.

Clark C. Heritage, formerly Technical Director, has been named Director of Development for the Weyerhaeuser Timber Co., with headquarters in the company's general offices in Tacoma, Wash.

Eugene F. Hickson, Chief, Paint, Varnish and Lacquer Section, Chemistry Div., National Bureau of Standards, Washington, D. C., has retired because of impaired health. Associated with the Bureau since 1919, Mr. Hickson has been affiliated with A.S.T.M. and Committee D-1 on Paint for the past 29 years, rendering important service on many of the D-1 subgroups. He also has been a member of Committee E-1 on Methods of Testing for many years.

E. E. Howe, formerly Manager, Ceramic Div., Lustron Corp., Columbus, Ohio, is now with the Chicago Vitreous Enamel Product Co., Cicero, Ill.

Melvin Wheeler Jackson is now Assistant Professor, University of Colorado, Boulder. He was previously on the faculty of the Georgia Institute of Technology, Atlanta.

James B. Kenny has been promoted from Assistant Chief Metallurgist to Chief Metallurgist of the Buchanan, Mich., plant of the Clark Equipment Co.

The Lebanon Steel Foundry, Lebanon, Pa., received the 1949 Award of Merit conferred by the American Association for State and Local History, for excellence of company publications promoting interests of the community.

James T. MacKenzie, Technical Director, American Cast Iron Pipe Co., Birmingham, Ala., has been named a trustee of the American Society for Metals.

Howard K. Nason, recently appointed Assistant to the Vice-President, Research and Development, Monsanto Chemical Co., St. Louis, Mo., was granted leave of absence to attend the advanced management program at Harvard University Graduate School of Business Administration.

John L. Parsons, Director of Research for the Hollingsworth & Whitney Co., has been appointed Technical Director of the northern mills, located at Waterville and Madison, Me.

John Chalmers Robinson, formerly Production Chief, Tennessee Eastman Corp., Oak Ridge, Tenn., is now Process Engineer, U. S. Atomic Energy Commission, Washington, D. C.

T. L. Robinson, President, The Wel-Met Co., Kent, Ohio, was re-elected Vice-President of the Metal Powder Association for the ensuing year.

L. P. Seyb, since 1942 a chemist and group leader in the Research Department, Diamond Alkali Co., Painesville, Ohio, has been named Manager of Research.

Charles H. Shepard, formerly Engineer, Ohio State Highway Testing & Research Lab., Ohio State University, Columbus, has been named Soils Engineer, Bureau of Construction, Ohio Department of Highways, Columbus.

Sam Tour, of Sam Tour & Co., Inc., the Graphitized Alloys Corp. and Forty-Four Trinity Place Corp., New York City, has been elected Chairman of the Inter Society Corrosion Committee of the National Association of Corrosion Engineers.

Kent R. Van Horn has been appointed Associate Director of Research, Aluminum Company of America. Until recently Dr. Van Horn had been an assistant director of research for the company, having charge of its branch laboratories at Cleveland since 1945. In assuming his new duties he has transferred to central headquarters of the research organization at New Kensington, Pa.

Evan W. Vaughan, formerly Associate Professor of Structural Engineering, College of Applied Science, Syracuse University, Syracuse, N. Y., is now Hydraulic Engineer, Canadian-Brazilian Services, Ltd., Toronto, Canada.

Griffith Williams, Jr., has accepted a position as Process Engineer, Bridgeport Brass Co., Indianapolis, Ind. He was previously associated with Revere Copper and Brass, Inc., Rome, N. Y.

Robert T. Wood has been named Chief Metallurgist of Magnesium Products, Aluminum Company of America, Pittsburgh. He had been associated with the American Magnesium Corp., an Alcoa subsidiary since 1922.

NECROLOGY...

The death of the following members has been reported

WILLIAM C. BAINBRIDGE, Technical Director, H. Kohnstamm and Co., Inc., Brooklyn, N. Y. (July 5, 1950). Member since 1928. Member of Committee D-1 on Paint, Varnish, Lacquer, and Related Products, and its Subcommittee on Methods of Chemical Analysis of Paint Materials since 1938; and of Committee

D-17 on Naval Stores, and its Subcommittee on Tall Oil (Liquid Rosin) since 1943.

ALMON L. BEALL, Research Engineer, Wright Aeronautical Corp., Wood-Ridge, N. J.; residence, Packanack Lake, N. J. (June 17, 1950). Member since 1933. Member of Technical Committee A on Gasoline of Committee D-2 on Petroleum Products and Lubricants for many years, and more recently member of Research Division on Volatility of D-2, as well as member of Technical Committee J on Aviation Fuels of the Petroleum Committee, serving on its sections on Volatility and Detonation, and as chairman of the latter subgroup since its organization in 1948. Also representative of the Society of Automotive Engineers since 1936 on A.S.A. Sectional Committee Z 11 on Petroleum Products and Lubricants.

FRANK A. BOND, Vice-President, The McKay Co., Pittsburgh, Pa. (July 3, 1950). Representative of company (formerly United States Chain & Forging Co.) membership since 1919, and representative of his company on Committee A-2 on Wrought Iron during this entire period, serving as Chairman of Subcommittee V on Chain Iron and Iron Chain since 1946; member of Joint Committee on Filler Metal and its Subcommittee on High Alloy Steel Filler Metal from 1943 to 1946.

CLAY BRIGGS, Chief Engineer, Cities Service Oil Co., Bartlesville, Okla. (February 18, 1950). Member since 1936.

ROBERT WHITE COLTMAN, Research Chemist, National Carbon Division, Union Carbide and Carbon Corp., Cleveland, Ohio (July 17, 1950). Member of the Society since 1919, and of Committee E-3 on Chemical Analysis of Metals and many of its subgroups since 1937, rendering important service in the development of the recently adopted procedures for the analysis of commercial zinc. Mr. Coltman had joined the National Carbon Research Laboratories in 1909, immediately after receiving his degree from the Technical School, Munich, Bavaria. As head of the Analytical Division, he was responsible for the development of many original methods for the analysis of manganese ores, dry cells, and illuminating carbons. His published work included papers on the analysis of manganese and on the gases from carbon arcs. In addition to his research activities, Mr. Coltman made translations of many French and German scientific papers. His hobby was the designing and making of clock mechanisms.

JOHN G. LUKASH, Research Chemist, H. Kohnstamm and Co., Inc., New York, N. Y. (June 3, 1950). Member since 1944, also member of Committee D-12 on Soaps and Other Detergents and of several of its subgroups.

R. G. MCELWEE, Manager, Foundry Alloy Div., Vanadium Corporation of America, Detroit, Mich. (June 21, 1950). Member since 1936, also member of Committee A-3 on Cast Iron and several of its subcommittees, and of Committee A-7 on Malleable-Iron Castings for the same period.

MAURICE J. MULLIGAN, Senior Research Chemist, General Motors Research Laboratories, Organic Chemistry Department, Detroit, Mich. (April 2, 1950). Born in Corunna, Ont., Canada, and educated at the University of Toronto, Mr. Mulligan joined General Motors Laboratories in 1928, his work covering a variety of special research problems, including studies of motor fuels. One of these projects led to the development of the present standard method for determination of gum in gasoline. Since Mr. Mulligan's affiliation with A.S.T.M. in 1948, he has been active in the work of the Research Divisions on Hydrocarbon Analysis, Analysis of Fuels, and Volatility of Committee D-2 on Petroleum Products and Lubricants, also on its Technical Committee on Light Hydrocarbons.

HOWARD M. SMITH, Metallurgist, Wyckoff Steel Co., Ambridge, Pa. (June 2, 1950). Representative of his company on Committee A-1 on Steel and its Subcommittee on Bar Steels since 1947.

S. D. ZUCKER, Samuel Greenfield Co., Inc., Buffalo, N. Y. (June 8, 1950). Representative of his company on Committee E-3 on Chemical Analysis of Metals since 1944, and on Committees B-5 on Copper and Copper Alloys, and B-7 on Light Metals and Alloys since 1949.

NEW MEMBERS . . .

The following 76 members were elected from June 11, 1950, to Aug. 9, 1950, making the total membership 6697 . . Welcome to A.S.T.M.

Note—Names are arranged alphabetically—company members first, then individuals

Chicago District

WISCONSIN POWER AND LIGHT CO., E. J. Kallevang, Chief Engineer, 122 W. Washington Ave., Madison 1, Wis.

CALVA, JOSE BARAQUIEL, Chemical Engineer, J. B. Calva and Co., 502 Kasota Bldg., Minneapolis 1, Minn.

HALEY, WILLIAM A., III, Assistant to Managing Director, American Concrete Pipe Assn., 228 N. LaSalle St., Chicago 1, Ill.

HENDRICKSON, JOHN G., JR., Research Engineer, Concrete Pipe Associations, Inc., 228 N. LaSalle St., Chicago 1, Ill.

HUBBARD, BRUCE W., Vice-President, Ideal Roller and Manufacturing Co., Inc., 2512 W. Twenty-fourth St., Chicago 8, Ill.

MATTHIAS, LYNN H., Director of Research, Allen-Bradley Co., Milwaukee 4, Wis.

POMEROY, ROBERT F., Research Engineer, General Lubricants Co., 206 Sixth St., N. E., Minneapolis 13, Minn. [J]*

SANDERS, A. L. R., Chief Engineer, Hazelet & Erdal, 53 W. Jackson Blvd., Chicago 4, Ill.

THOMAS, WILLIAM C., Manager, Laboratory Equipment Div., Lindberg Engineering Co., 2450 W. Hubbard St., Chicago 12, Ill.

Cleveland District

RAND AND ASSOCIATES, H. J., W. H. Nichols, Chief Engineer, 12720 Lakeshore Blvd., Cleveland 8, Ohio.

To the A.S.T.M. Committee on Membership

1916 Race St., Philadelphia 3, Pa.

Gentlemen:

Please send me information on membership in A.S.T.M. and include a membership application blank

Signed _____

Address _____

_____

Date _____

Barber, C. Merrill, Partner, Barber & Magee, 1900 Euclid Ave., Cleveland 15, Ohio.
Borton, Homer T., Chief Structural Engineer, The Osborn Engineering Co., 7016 Euclid Ave., Cleveland 3, Ohio.
Bunnell, Lowell A., Ceramic Engineer, Colonial Insulator Co., 973 Grant St., Akron 11, Ohio.
Little, Jess C., Technical Engineer, American Steel and Wire Co., Rockefeller Bldg., Cleveland, Ohio.
Sawyer, E. C., Sales Manager, Central Silica Co., Masonic Temple Bldg., Zanesville, Ohio.

Detroit District

Pressed Metals of America, Inc., Malcolm G. Simons, Plant Metallurgist, Box 449, Port Huron, Mich.
Kuentzel, L. E., Head, Physics Research Labs., Wyandotte Chemicals Corp., Wyandotte, Mich.
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Investigation of Bearing Materials Under Various Degrees of Lubrication in the Low-Speed Range

By Louis A. Nowell, Jr.[1]

Synopsis

This is the first progress report of an investigation to measure the differences in several bearing materials under varying conditions of lubrication. The report is concerned with the steps taken to adapt an Amsler wear testing machine to this purpose. Results are presented to demonstrate that the operating conditions of the bearings have been brought under sufficient control to provide a reasonably satisfactory test procedure.

The control experiments presented herein were conducted on 30- and 60-deg., steel-backed, Navy Grade 2 tin-base babbitt bearings operating on a 2-in. diameter journal. Diametrical clearances varied from 0 to 0.004 in. Navy symbol 2190-T oil was employed. The studies covered a range of speeds from 25 rpm. to 350 rpm. and loads from 40 to 900 psi. Measurements were made of friction and of oil and bearing temperatures. Observations were obtained on the electrical properties of the oil film. It was found that a 60-deg. bearing, with a 0.004-in. clearance, gave reproducible results as evidenced by plots on the f *versus* ZN/P parameters.

THE ultimate objective of this test is to determine the frictional properties of bearing materials under varying degrees of lubrication from a complete hydrodynamic condition, through boundary lubrication, and thence to absence of lubrication. To reach this objective it was necessary to develop apparatus and procedures capable of controlling the many variables incident to the operation of a journal bearing. The task proved to be most difficult. Nearly one and a half years elapsed between the time the basic test machines were obtained and the time that satisfactory procedures had been established and tried. The present report summarizes this initial phase and describes in some detail the final form of the equipment. Also included are the results of standardization runs, made with grade 2 tin-base babbitt which is to serve as a standard of comparison in subsequent work.

Description of Material

All bearings used in the tests were made of Navy Grade 2 tin-base babbitt with the following approximate characteristics:

Composition, per cent

Tin	89	Iron	0.08 max.
Antimony	7.5	Arsenic	0.10 max.
Lead	0.35	Zinc	Nil
Copper	3.5	Aluminum	Nil

Properties

Elastic limit at	20 C	3350 psi.
	100 C	1100 psi.
Brinell hardness at	20 C	24½
	100 C	12
Melting point		466 F.

The test bearings were poured in the laboratory using the specially designed casting furnace and mold shown in Fig. 1. The equipment was designed to provide accurate temperature control of the melt and of the mold. A bottom-pouring crucible, with a spring-actuated plug, provided close control of the quantity and cleanliness of the poured babbitt.

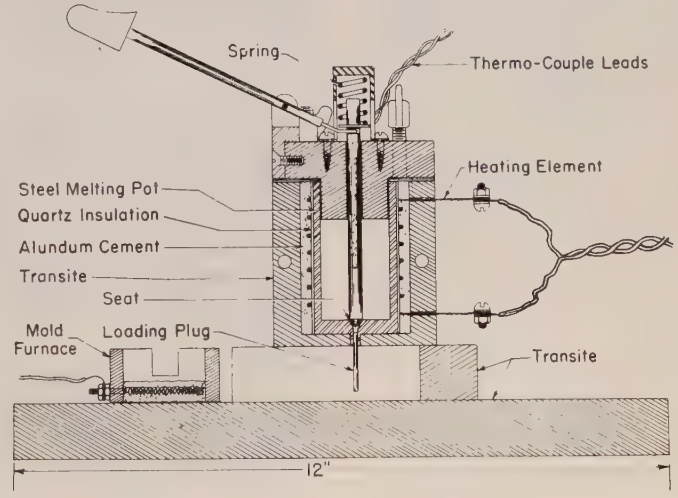

Fig. 1.—Bearing Mold and Casting Furnace.

In the preparation of the bearings, the steel shells were machined to a 1-in. radius and were babbitted as follows:

(*a*) Clean 5 min. in hot 5 per cent NaOH.
(*b*) Etch 1 min. in boiling 10 per cent HCl.
(*c*) Flux with saturated $ZnCl_2$.
(*d*) Immerse 20 sec. in 100 per cent tin.
(*e*) Cool to room temperature, and abrade the surface.
(*f*) Heat shell in mold to 350 F.
(*g*) Pour 1-in. thick babbitt at 660 F.
(*h*) Air cool.

The bearing journals were machined from S.A.E. No. 1020 steel with a Brinell hardness of 110. The finish was 4 to 6 root mean square microinches as measured with a profilometer.

Navy 2190-T oil was used as a lubricant in the tests. Typical properties of the oil were as follows:

Specific gravity 60/60 F	0.9212
Gravity, deg. A.P.I.	22.1
Flash point, deg. Fahr.	410
Fire point, deg. Fahr.	455
Viscosity, Saybolt Universal Seconds	
at 100 F	499.0
at 130 F	193.0
at 210 F	53.1
Neutralization number	0.04
Saponification number	0.17
Interfacial tension	28.9
Specific heat at 130 F	0.465
at 160 F	0.480
at 190 F	0.495
Dielectric constant	2.283
Dielectric strength, 1/10 in., kv	30–35

Method of Test

Perhaps the nearest approach to a standard wear testing machine is the one manufactured by Alfred J. Amsler. The device is quite well known to those engaged in wear problems. The Amsler machine was selected for this investigation because it contained the necessary basic machine elements. The test journals and bearings could be installed easily. Tests could be made under loads varying between 40 and 900 lb. Of particular interest and usefulness was the sensitive torque-indicating device for the measurement of bearing friction.

Many previous investigators had used the Amsler machine for the study of

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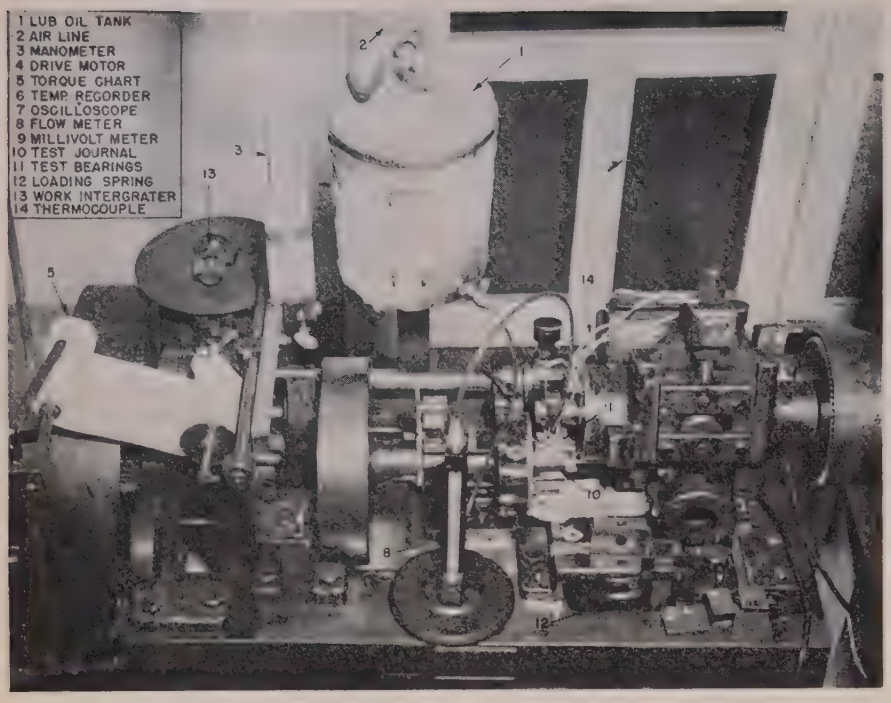


Fig. 2.—Test Equipment.

various bearing problems. However, none of the setups produced sufficient control of the variables to enable accurate calculations of the ZN/P parameter. Lacking a suitable procedure for such an evaluation on small segment bearings, the major portion of the work was devoted to experimenting with equipment modifications until the desired end point was realized.

Figures 2, 3, and 4 show the equipment layout. The uses for the various auxiliary pieces will be described later. As far as the basic machine was concerned, the most important modification consisted of providing a 5-hp. d-c. variable-speed motor for the study of the ZN/P relationship. The motor voltage was supplied by a motor generator set with a variable field voltage. Speed variation was obtained with a set of slide wire resistors. Figure 5 is a circuit diagram of the speed control system.

The initial experiments were made with 30-deg. segment bearings like that shown in Fig. 6. Later these were abandoned in favor of 60-deg. bearings as shown in Fig. 7. Since one of the ultimate aims of the test was to find a reproducible way to make interrupted oil flow studies, four different methods of lubrication were tried. A summary of the bearing and lubrication combinations is given in Table 1.

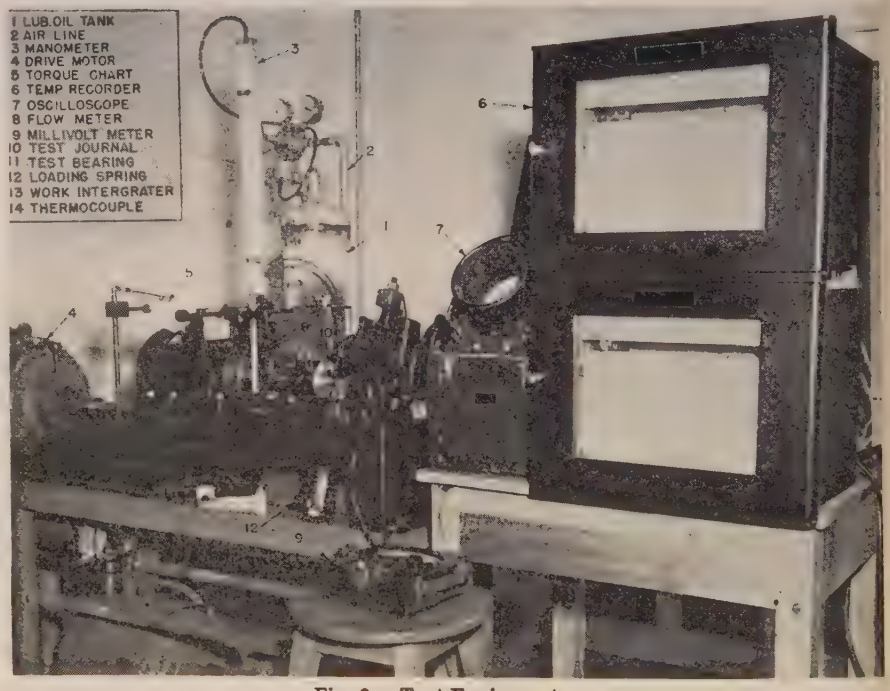


Fig. 3.—Test Equipment.

TABLE I.—BEARING AND LUBRICATION COMBINATIONS.

Method of Alignment	Arc of Bearings, deg.	Diameter of Journal, D, in.	Length, L, in.		Ratio, Length to Diameter, L/D	Ratio, Clearance to Diameter, C/D	Method of Lubrication	
			Bearing	Journal			Gravity	Pressure
Rigid....	30	2.000	0.4	0.4	0.2	0.000	Drops	...
Ball socket	60	2.000	1.0	1.25	0.5	0.004	Immersion bath	...
Ball socket	60	2.000	1.0	1.25	0.5	0.004	...	Lucite dam
Ball socket	60	2.000	1.0	1.25	0.5	0.004	...	Oil groove

The oil was fed by gravity to the 30-deg. bearings; the oil dropped onto the journal and was carried by adhesion into the bearing. The same method was tried with the first 60-deg. bearing, but better lubrication resulted by allowing the journal to operate partially submerged in an oil bath. The third system of lubrication employed a lucite dam attached by screws to the leading edge of the bearings; the lubricant was fed, under a pressure of 6 in. of mercury, directly into a distributing groove cut in the dam. The pressure system was composed of a filtered air supply, control valves, a mercury manometer, and a float type flowmeter.

The fourth method listed in the table was finally adopted as the standard procedure. In this case the oil was forced by pressure through the flowmeter and into a distributing groove cut in the babbitt. The groove was 0.136 in. wide, 0.80 in. long, and 0.125 in. deep; it was located 0.064 in. from the leading edge of the bearing. After passing through the bearing, the oil was disposed of without reuse. The inlet oil entered at room temperature, which was measured with an electronic recording potentiometer.

All four of the methods described above gave about the same f value at a given ZN/P value. However, the drop, bath, and lucite dam methods were not satisfactory for the purpose of interrupted oil flow tests, because on interruption of the oil supply it was not possible to control or measure the quantity of oil adhering to the journal.

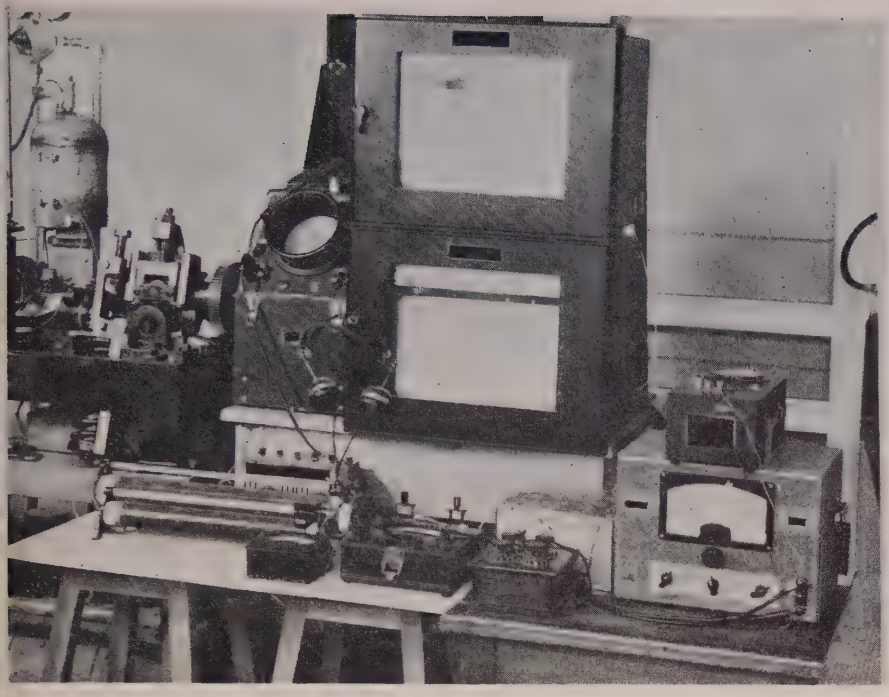


Fig. 4.—Test Equipment.

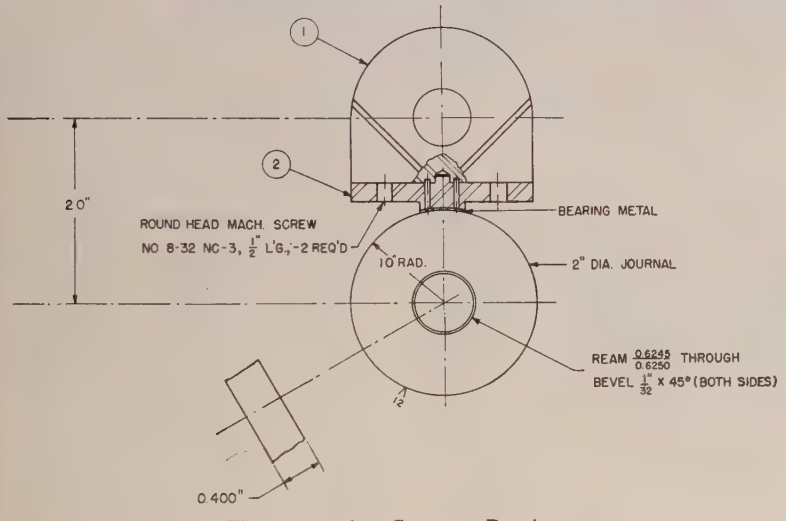


Fig. 6.—30-deg. Segment Bearing.

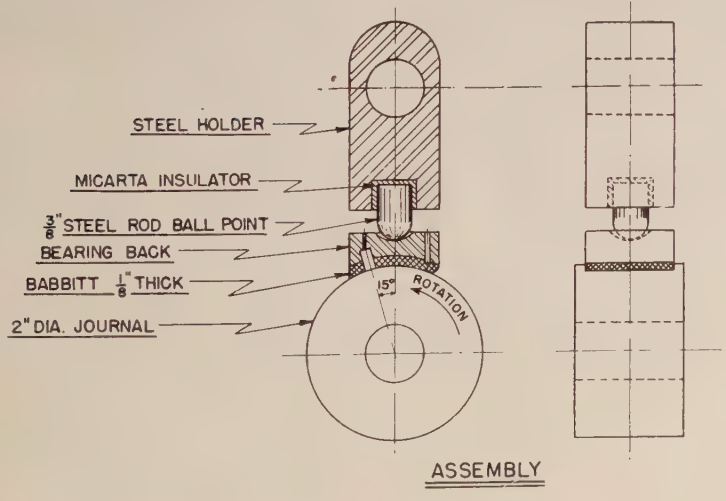
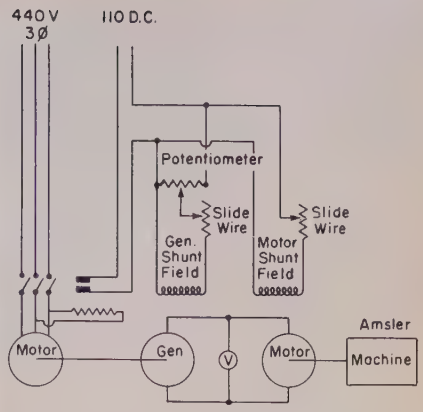


Fig. 7.—60-deg. Bearing.



Constant Torque up to E_A = 110 Volts
E_A = 110 — Speed 1700 RPM.
E_A = 55 — Speed 850 RPM
E_A = 11 — Speed 170 RPM
E_A = 5.5 — Speed 85 RPM
Constant H.P. Above E_A = 110 Volts

Fig. 5.—Speed Control Circuit.

The use of the oil groove method is believed to provide a reproducible interruption procedure.

The test bearings were centrally loaded with a calibrated coil spring. The 30-deg. bearings were fixed in their holders. The 60-deg. bearings were mounted on ball points to allow better seating on the journal. In all cases the bearing holder was free to move up or down with the loading head.

The test journals were press fitted to the Amsler machine drive shaft and were secured with a nut. The drive shaft was supported near the test journal by double-row self-aligning ball bearings, No. 1306. The shaft was connected on the other end to the friction dynamometer and torque indicator, to which was attached a continuously recording strip chart. The chart provided a permanent record of torque readings.

A convenient graphical method was employed to present test results. The method was originated by Hersey (**1**)[2] and was used by Wilson and Barnard (**2**). The method compares the coefficient of friction curves for bearings by plotting the coefficient of friction, f, against the generalized operating variable, ZN/P, in which Z = viscosity in centipoises, N = speed in rpm., and P = bearing pressure in psi. The justifications and advantages of the generalized variable, in lieu of separate operating factors, have been enumerated by McKee (**3**) and Boswall (**4**).

At first a constant value of 160 centipoises was assumed for the oil viscosity. Later, in the case of some of the 60-deg. bearings, the viscosity was

[2] The boldface numbers in parentheses refer to the list of references appended this paper.

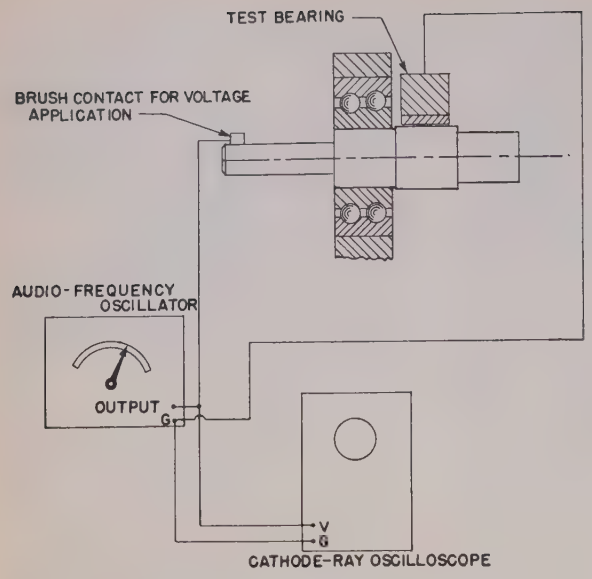


Fig. 8.—Schematic Diagram of Experimental Setup for Determination of Minimum Oil Film Thickness.

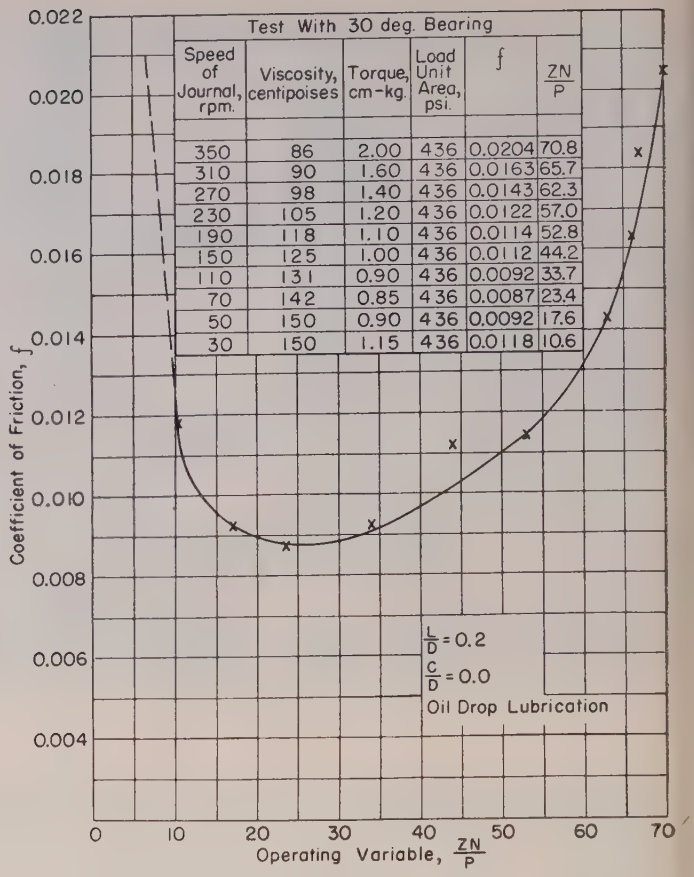


Fig. 9.—Test with 30-deg. Bearing.

calculated from temperature measurements. The measurements were obtained with a copper-constantan thermocouple mounted in, but insulated from, the bearing alloy $\frac{1}{4}$ in. from the trailing edge. The thermocouple location is indicated in Fig. 7. During each test run the machine was allowed to reach equilibrium at each load and speed combination before temperature and torque readings were taken.

During the course of the tests, it was found that the assumed value of 160 centipoises gave practically the same results as those obtained with calculated viscosities. The minimum f *versus* ZN/P values were nearly identical. However, the calculated values resulted in a somewhat steeper curve to the right of the critical point. Since the calculated values represent the actual viscosities for all practical purposes, they have been used in all subsequent tests.

Attempts were made to determine by electrical means the location of the transition zone from fluid lubrication to boundary lubrication. The method employed the output of an audio frequency oscillator applied to the vertical plates of a cathode-ray polar coordinate indicator in parallel with a path to ground through the bearing. The circuit is shown schematically in Fig. 8. The amplitude of the wave is a function of the resistance supplied by the film of oil, which in turn is a function of the film thickness, dielectric properties, and the presence of moisture or other contamination.

During a typical test run the Amsler machine was allowed to operate at top speed (350 rpm.) for about 10 min. The oil supply then was turned on and the bearing brought in contact with the rotating journal. A constant predetermined load was applied to the bearing. At the end of each 10-min. interval, the speed was reduced by 25 rpm. until the critical ZN/P value had been passed. Records were taken of speed, torque, oil temperature, room temperature, oil inlet pressure, rate of oil flow, and oscillograph indications of oil film condition.

In addition to the variable speed procedure, similar tests also were made with the speed constant and the load variable. The same ZN/P curves were plotted. All bearings were tested without a prior run-in.

Results of Tests

For ease of comparison, the test results are presented graphically in Figs. 9 to 13, inclusive. Each graph is accompanied by a tabulation of the pertinent data.

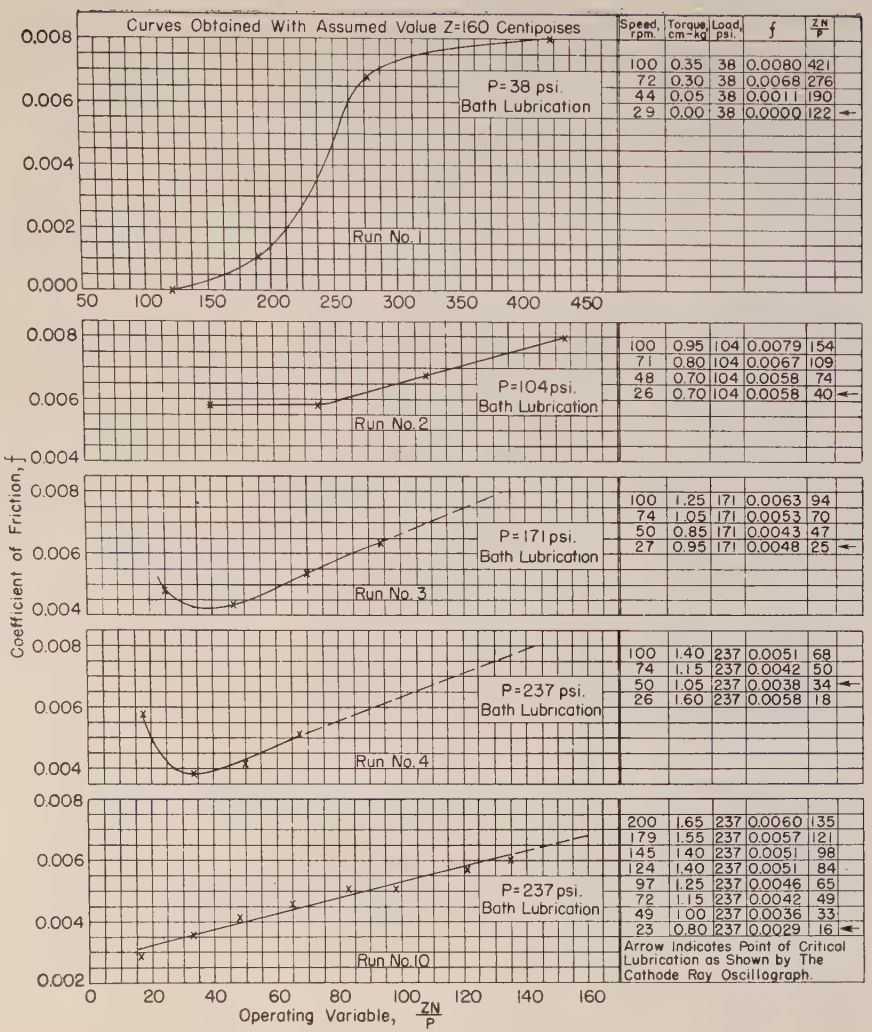
Figure 9 includes the results of a typical test with a 30-deg. segment bearing. The relatively high coefficients of friction probably were caused by the low L/D value rather than by the limitation imposed by the subtended angle *per se*. The L/D value of 0.2 was sufficient reason to expect high f values due to excessive side leakage of the lubricant.

The 60-deg. bearings had an L/D ratio of 0.5. These bearings showed frictional properties in accordance with accepted ideas for bearings of this design. The results obtained with the 60-deg. bearings are presented in Figs. 10 through 13. The general order of presentation is according to increasing unit loads on the bearings.

The first curve in Fig. 10 shows one section at which the coefficient of friction is zero. This probably was caused by the inability of the dynamometer to record the small amount of friction developed with the very light load of 38 psi. and the low speed of 29 rpm. The curves with the higher loads are normal in appearance.

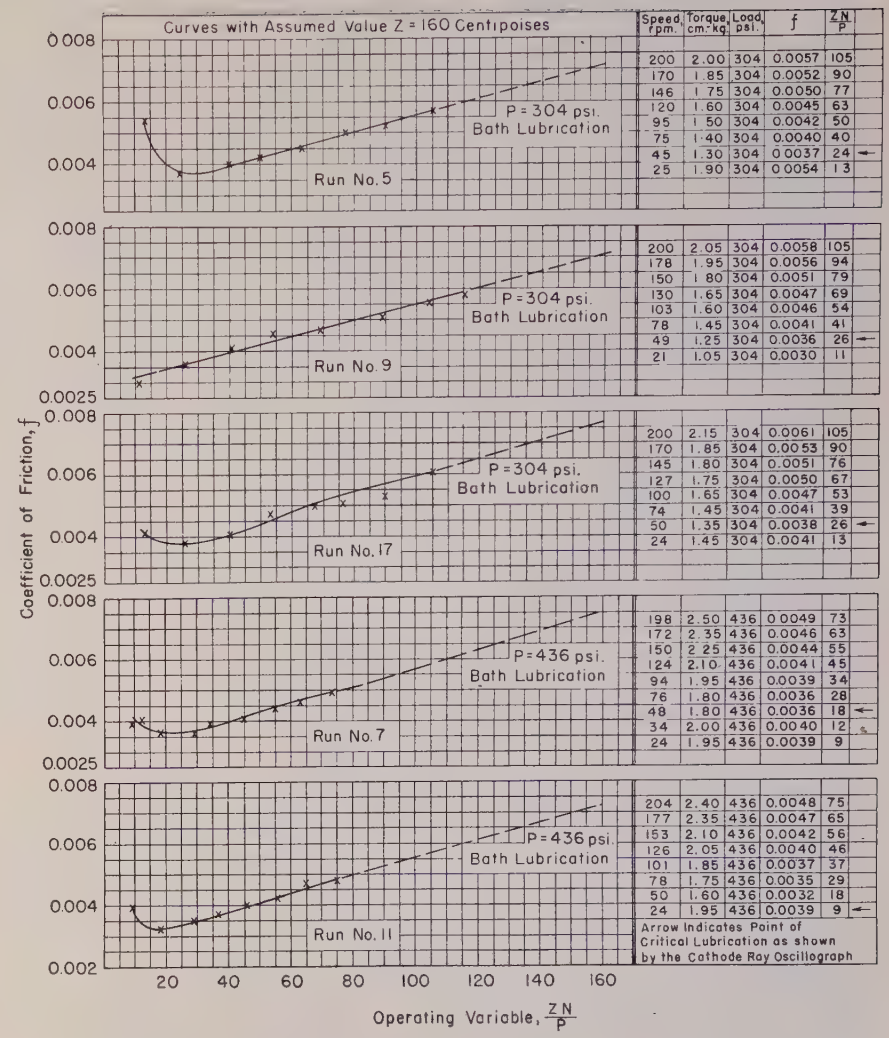
Beginning in Fig. 10, and continuing through the first two curves in Fig. 13, are presented the results of the tests in which the speed was the variable and in which the load was held constant during each run. The last four curves in Fig. 13 were made at constant speeds and variable loads.

Except for the four cases indicated, all of the test runs were plotted using an assumed viscosity value of $Z = 160$ centipoises. The other four runs were made with viscosities calculated from temperature readings taken during the tests. This latter method is considered to be more accurate. The two curves


Curves Obtained With Assumed Value Z=160 Centipoises
P=38 psi. Bath Lubrication
Run No. 1
P=104 psi. Bath Lubrication
Run No. 2
P=171 psi. Bath Lubrication
Run No. 3
P=237 psi. Bath Lubrication
Run No. 4
P=237 psi. Bath Lubrication
Run No. 10
Coefficient of Friction, f
Operating Variable, ZN/P
Arrow Indicates Point of Critical Lubrication as Shown by The Cathode Ray Oscillograph.

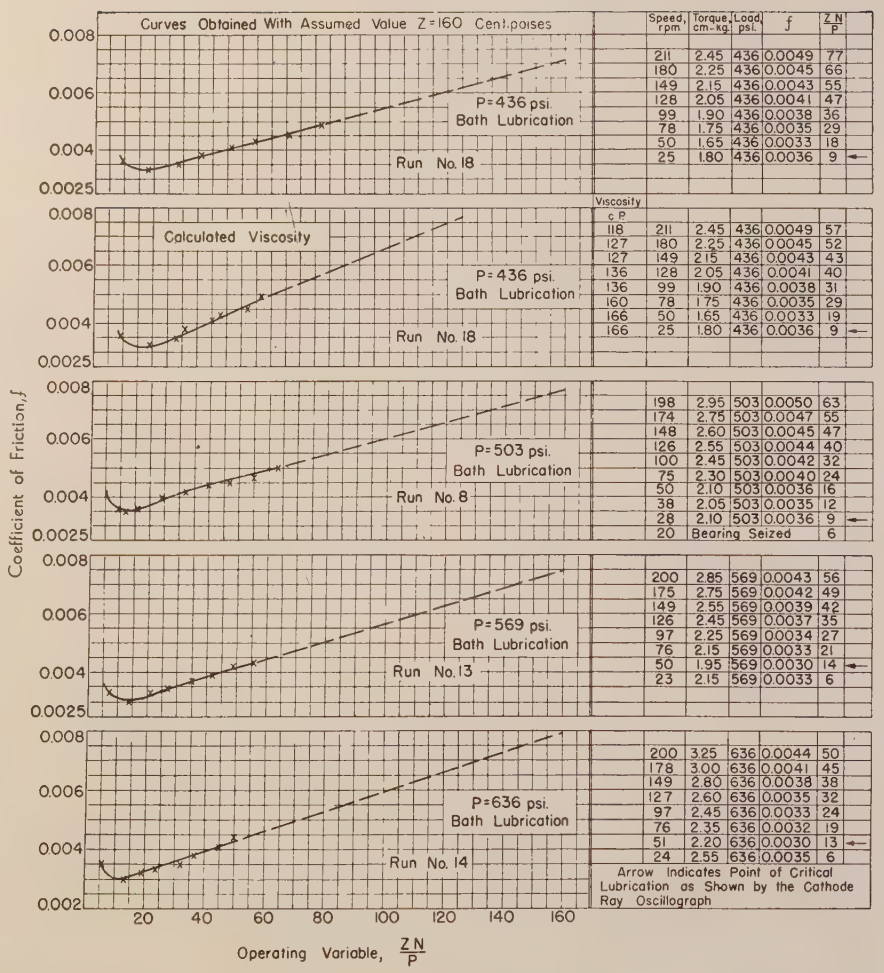
Speed, rpm.	Torque, cm-kg	Load, psi.	f	ZN/P
100	0.35	38	0.0080	421
72	0.30	38	0.0068	276
44	0.05	38	0.0011	190
29	0.00	38	0.0000	122 ←
100	0.95	104	0.0079	154
71	0.80	104	0.0067	109
48	0.70	104	0.0058	74
26	0.70	104	0.0058	40 ←
100	1.25	171	0.0063	94
74	1.05	171	0.0053	70
50	0.85	171	0.0043	47
27	0.95	171	0.0048	25 ←
100	1.40	237	0.0051	68
74	1.15	237	0.0042	50
50	1.05	237	0.0038	34 ←
26	1.60	237	0.0058	18
200	1.65	237	0.0060	135
179	1.55	237	0.0057	121
145	1.40	237	0.0051	98
124	1.40	237	0.0051	84
97	1.25	237	0.0046	65
72	1.15	237	0.0042	49
49	1.00	237	0.0036	33
23	0.80	237	0.0029	16 ←

Fig. 10.—Tests with 60-deg. Bearing $L/D = 0.5$ $C/D = 0.002$.


Curves with Assumed Value Z = 160 Centipoises
P = 304 psi. Bath Lubrication
Run No. 5
P = 304 psi. Bath Lubrication
Run No. 9
P = 304 psi. Bath Lubrication
Run No. 17
P = 436 psi. Bath Lubrication
Run No. 7
P = 436 psi. Bath Lubrication
Run No. 11
Coefficient of Friction, f
Operating Variable, ZN/P
Arrow Indicates Point of Critical Lubrication as shown by the Cathode Ray Oscillograph

Speed, rpm.	Torque, cm-kg	Load, psi.	f	ZN/P
200	2.00	304	0.0057	105
170	1.85	304	0.0052	90
146	1.75	304	0.0050	77
120	1.60	304	0.0045	63
95	1.50	304	0.0042	50
75	1.40	304	0.0040	40
45	1.30	304	0.0037	24 ←
25	1.90	304	0.0054	13
200	2.05	304	0.0058	105
178	1.95	304	0.0056	94
150	1.80	304	0.0051	79
130	1.65	304	0.0047	69
103	1.60	304	0.0046	54
78	1.45	304	0.0041	41
49	1.25	304	0.0036	26 ←
21	1.05	304	0.0030	11
200	2.15	304	0.0061	105
170	1.85	304	0.0053	90
145	1.80	304	0.0051	76
127	1.75	304	0.0050	67
100	1.65	304	0.0047	53
74	1.45	304	0.0041	39
50	1.35	304	0.0038	26 ←
24	1.45	304	0.0041	13
198	2.50	436	0.0049	73
172	2.35	436	0.0046	63
150	2.25	436	0.0044	55
124	2.10	436	0.0041	45
94	1.95	436	0.0039	34
76	1.80	436	0.0036	28
48	1.80	436	0.0036	18 ←
34	2.00	436	0.0040	12
24	1.95	436	0.0039	9
204	2.40	436	0.0048	75
177	2.35	436	0.0047	65
153	2.10	436	0.0042	56
126	2.05	436	0.0040	46
101	1.85	436	0.0037	37
78	1.75	436	0.0035	29
50	1.60	436	0.0032	18
24	1.95	436	0.0039	9 ←

Fig. 11.—Tests with 60-deg. Bearings $L/D = 0.5$ $C/D = 0.002$.


Curves Obtained With Assumed Value Z=160 Centipoises
P=436 psi. Bath Lubrication
Run No. 18
Calculated Viscosity
P=436 psi. Bath Lubrication
Run No. 18
P=503 psi. Bath Lubrication
Run No. 8
P=569 psi. Bath Lubrication
Run No. 13
P=636 psi. Bath Lubrication
Run No. 14
Coefficient of Friction, f
Operating Variable, ZN/P
Arrow Indicates Point of Critical Lubrication as Shown by the Cathode Ray Oscillograph

Speed, rpm	Torque, cm-kg	Load, psi	f	ZN/P
211	2.45	436	0.0049	77
180	2.25	436	0.0045	66
149	2.15	436	0.0043	55
128	2.05	436	0.0041	47
99	1.90	436	0.0038	36
78	1.75	436	0.0035	29
50	1.65	436	0.0033	18
25	1.80	436	0.0036	9 ←

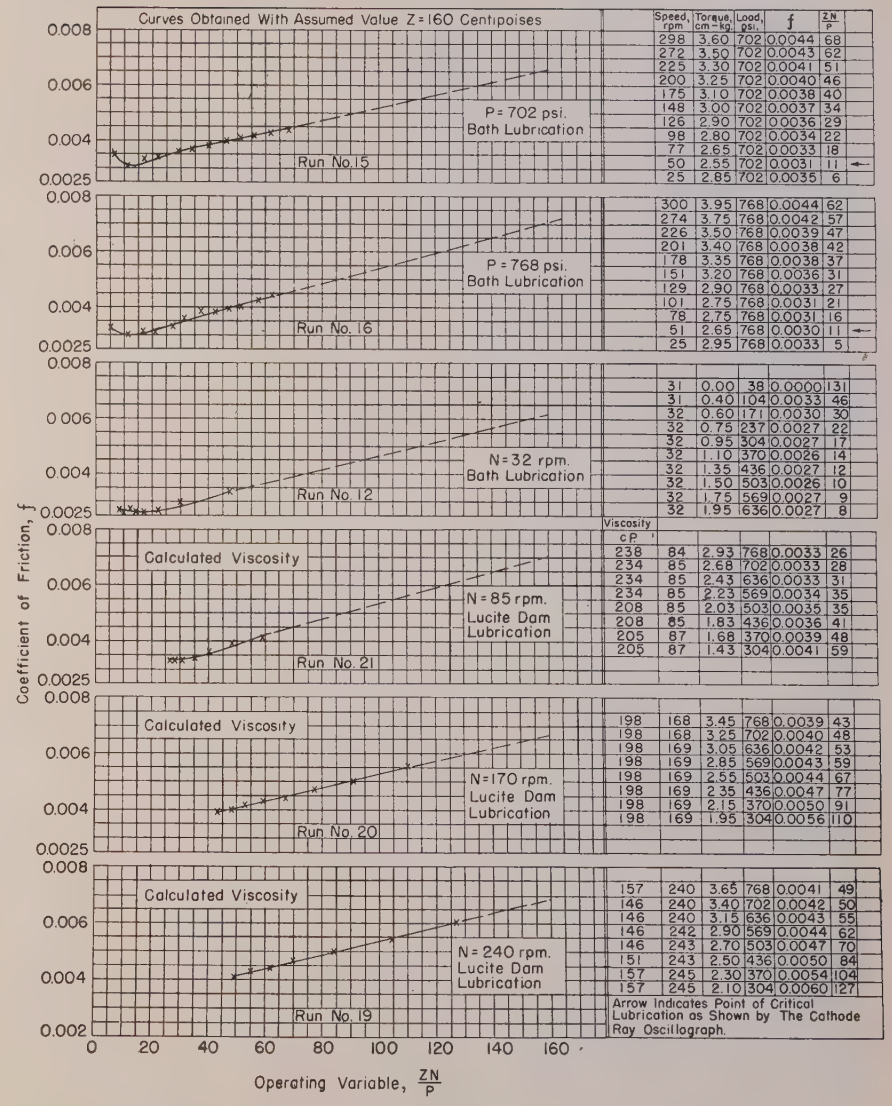
Viscosity c.P.					
118	211	2.45	436	0.0049	57
127	180	2.25	436	0.0045	52
127	149	2.15	436	0.0043	43
136	128	2.05	436	0.0041	40
136	99	1.90	436	0.0038	31
160	78	1.75	436	0.0035	29
166	50	1.65	436	0.0033	19
166	25	1.80	436	0.0036	9 ←

198	2.95	503	0.0050	63
174	2.75	503	0.0047	55
148	2.60	503	0.0045	47
126	2.55	503	0.0044	40
100	2.45	503	0.0042	32
75	2.30	503	0.0040	24
50	2.10	503	0.0036	16
38	2.05	503	0.0035	12
28	2.10	503	0.0036	9 ←
20	Bearing Seized			6

200	2.85	569	0.0043	56
175	2.75	569	0.0042	49
149	2.55	569	0.0039	42
126	2.45	569	0.0037	35
97	2.25	569	0.0034	27
76	2.15	569	0.0033	21
50	1.95	569	0.0030	14 ←
23	2.15	569	0.0033	6

200	3.25	636	0.0044	50
178	3.00	636	0.0041	45
149	2.80	636	0.0038	38
127	2.60	636	0.0035	32
97	2.45	636	0.0033	24
76	2.35	636	0.0032	19
51	2.20	636	0.0030	13 ←
24	2.55	636	0.0035	6

Fig. 12.—Tests with 60-deg. Bearings $L/D = 0.5$ $C/D = 0.002$.


Curves Obtained With Assumed Value Z=160 Centipoises
P=702 psi. Bath Lubrication
Run No. 15
P=768 psi. Bath Lubrication
Run No. 16
N=32 rpm. Bath Lubrication
Run No. 12
Calculated Viscosity
N=85 rpm. Lucite Dam Lubrication
Run No. 21
Calculated Viscosity
N=170 rpm. Lucite Dam Lubrication
Run No. 20
Calculated Viscosity
N=240 rpm. Lucite Dam Lubrication
Run No. 19
Coefficient of Friction, f
Operating Variable, ZN/P
Arrow Indicates Point of Critical Lubrication as Shown by The Cathode Ray Oscillograph.

Speed, rpm	Torque, cm-kg	Load, psi	f	ZN/P
298	3.60	702	0.0044	68
272	3.50	702	0.0043	62
225	3.30	702	0.0041	51
200	3.25	702	0.0040	46
175	3.10	702	0.0038	40
148	3.00	702	0.0037	34
126	2.90	702	0.0036	29
98	2.80	702	0.0034	22
77	2.65	702	0.0033	18
50	2.55	702	0.0031	11 ←
25	2.85	702	0.0035	6

300	3.95	768	0.0044	62
274	3.75	768	0.0042	57
226	3.50	768	0.0039	47
201	3.40	768	0.0038	42
178	3.35	768	0.0038	37
151	3.20	768	0.0036	31
129	2.90	768	0.0033	27
101	2.75	768	0.0031	21
78	2.75	768	0.0031	16
51	2.65	768	0.0030	11 ←
25	2.95	768	0.0033	5

31	0.00	38	0.0000	131	
31	0.40	104	0.0033	46	
32	0.60	171	0.0030	30	
32	0.75	237	0.0027	22	
32	0.95	304	0.0027	17	
32	1.10	370	0.0026	14	
32	1.35	436	0.0027	12	
32	1.50	503	0.0026	10	
32	1.75	569	0.0027	9	
32	1.95	636	0.0027	8	

Viscosity c.P.					
238	84	2.93	768	0.0033	26
234	85	2.68	702	0.0033	28
234	85	2.43	636	0.0033	31
234	85	2.23	569	0.0034	35
208	85	2.03	503	0.0035	35
208	85	1.83	436	0.0036	41
205	87	1.68	370	0.0039	48
205	87	1.43	304	0.0041	59

198	168	3.45	768	0.0039	43
198	168	3.25	702	0.0040	48
198	169	3.05	636	0.0042	53
198	169	2.85	569	0.0043	59
198	169	2.55	503	0.0044	67
198	169	2.35	436	0.0047	77
198	169	2.15	370	0.0050	91
198	169	1.95	304	0.0056	110

157	240	3.65	768	0.0041	49
146	240	3.40	702	0.0042	50
146	240	3.15	636	0.0043	55
146	242	2.90	569	0.0044	62
146	243	2.70	503	0.0047	70
151	243	2.50	436	0.0050	84
157	245	2.30	370	0.0054	104
157	245	2.10	304	0.0060	127

Fig. 13.—Tests with 60-deg. Bearings $L/D = 0.5$ $C/D = 0.002$.

shown at the top of Fig. 12 illustrate the differences in the curves as obtained by both methods when applied to the same test run. The principal difference is the steeper slope of the calculated viscosity curve to the right of the critical zone.

The arrow beside each table of data represents the location of the critical point as first observed by the oscilloscope indications. An excellent agreement is apparent between these points and the criticals as found by the friction coefficient measurements.

Discussion

As shown by the results, much has been accomplished toward developing a simple bearing material test. It is necessary, however, to develop a single parameter embodying at least ZN/P and perhaps ZN/P, C/D, Q terms. The necessity for such development seems obvious in view of the number of tests that would be required if such parameter is not fully proved.

In this connection runs Nos. 18, 19, 20, and 21 may be compared. Run No. 18 at constant load and varying speed may be represented by the equation

$$f = 0.0025 + 0.00028\frac{ZN}{P}$$

Runs Nos. 19, 20, and 21 made at constant speeds and varying loads may be represented by the equation

$$f = 0.0025 + 0.0004\frac{ZN}{P}$$

These are the only runs on which complete viscosity data are available, but run 18 was not made on the same bearing as runs Nos. 19, 20, and 21. Special jigs required for the accurate determination of the clearance of these bearings were not completed until after these runs had been made. The test bearings may have differed sufficiently in clearance to account for the discrepancy in results.

The electrical methods used in this study indicate the onset of boundary lubrication more readily than friction or temperature measurements. It is believed that the use of such methods will permit quantitative determination of the bearing behavior during reduced oil flows.

Conclusions

Based on the evidence in this report, it is concluded that the Amsler testing machine, as modified, shows excellent promise as a means for investigating the effect of varying degrees of lubrication (from fluid to boundary, thence to absence of lubrication) on the frictional properties of different bearing alloys. It is possible to obtain reasonably accurate data on oil film and bearing alloy temperatures, rate of oil flow through the bearing, journal speed, total load, frictional torque, and electronic indication of oil film continuity. The Amsler machine is adaptable to testing of a variety of bearing and journal materials including plastics. Tests can be conducted with various lubricants, corrosive media or abrasive particles.

References

(1) M. D. Hersey, "On the Laws of Lubrication of Journal Bearings," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 37 167–202 (1915).

(2) R. E. Wilson and D. P. Barnard, "The Mechanism of Lubrication," *Transactions*, Soc. Automotive Engrs. Vol. 51, pp. 203–238 (1922).

(3) S. A. McKee and T. R. McKee, "Friction of Journal Bearings as Influenced by Clearance and Length," *Transactions*, Am. Soc. Mechanical Engrs., Vol. APM-51-15, pp. 161–171 (1929).

(4) R. O. Boswall, "Film Lubrication of the Journal Bearing," *Proceedings*, Inst. Mechanical Engrs. (London), Vol. 122, April, 1932, pp. 423–517.

Effect of Fungus Growth on the Tensile Strength of Polyvinyl Chloride Films Plasticized with Three Plasticizers

By Sigmund Berk[1]

Synopsis

Polyvinyl chloride films plasticized with three plasticizers were inoculated with a species of *Trichoderma* and incubated on mineral salts agar. The film plasticized with a mixture of dibutyl sebacate and dioctyl phthalate was very susceptible to mold attack whereas the films plasticized with dioctyl phthalate or butadiene-acrylonitrile were mold inert.

Tensile strength tests conducted on the films exposed to mold growth for 6 weeks showed that the formulation with dibutyl sebacate had a 63 per cent increase in tensile strength and a 67 per cent loss in percentage elongation over the unincubated controls. The large increase in tensile strength is attributed to the removal of plasticizer by the fungus. The films with the other two plasticizers had no appreciable changes in tensile strength and percentage elongation.

Changes in tensile strength and percentage elongation may be used as a criterion for measuring the degradation of plastics by fungi.

A number of criteria can be used to measure the extent of damage to plastics by fungi and to determine the effect of the fungus growth on the plastic material. These criteria are: (1) visual examination of extent and profuseness of fungus growth, (2) weight of the fungus mat produced on the plastic sample, (3) loss in weight of the plastic after fungus growth is removed from the surface of the sample, (4) decrease in surface and volume insulation resistivity, (5) measurement of loss of components in plastic by use of stable or radioactive isotopes in the resins, plasticizers, fillers, and stabilizers, (6) loss in flexibility (increase in stiffness), and (7) other mechanical methods such as changes in the tensile strength and percentage elongation.

The most widely used method in determining the fungus deterioration of plastics is the visual evaluation (macro or micro) of the amount of fungus growth on the sample. Harvey and Meloro (5)[2] used a stiffness test to evaluate the degradation of vinyl and polyvinyl butyral films by fungi. Leutritz (6, 7) measured the loss in insulation resistance of plastics that were incubated at high humidity and that had abundant fungus growth. He concluded that the lowered insulation resistance is chiefly a moisture phenomenon since the resistance is restored when the plastic is dried. Blake and Kitchin (3)

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

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[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

TABLE I.—COMPOSITIONS OF PLASTIC FORMULATIONS.

		Per Cent, by Weight
No. 1...	Polyvinyl chloride resin (Geon 101)	13.5
	Plasticizers plus additives:	
	dioctyl phthalate 43.5%	6.5
	dibutyl sebacate 33.5%	
	white mineral oil 13.0%	
	stabilizer (lead naphthenate plus mineral spirits) 10.0%	
	Solvents (1 part mineral spirits: 4 parts methyl isobutyl ketone)	80.0
No. 2...	Polyvinyl chloride resin (Geon 101)	13.5
	Plasticizer plus additives:	
	dioctyl phthalate 77.0%	6.5
	white mineral oil 13.0%	
	stabilizer (same as No. 1) 10.0%	
	Solvents (same as No. 1)	80.0
No. 3...	Polyvinyl chloride resin (Geon 101)	9.0
	Plasticizer:	
	butadiene-acrylonitrile (Hycar OR25)	9.0
	Solvents:	
	methyl isobutyl ketone	73.0
	hydrocarbon	8.0
	Stabilizer solution	1.0

measured leakage through rubber cable insulation and found that the growth of microorganisms produced discrete low resistance spots. Stief and Boyle (9) found no significant loss in the tensile strength of natural, GR-S, and Neoprene rubber due to fungus attack after soil burial tests. However, there is no report in the literature that significant changes in the tensile strength and percentage elongation of polyvinyl chloride films may be obtained by exposure to fungi and that increases in the tensile strength may be used as a measure of the removal of plasticizer by fungi.

Preparation of Plastic Films

The composition of the three plastic formulations used is given in Table I. The polyvinyl chloride dispersion was prepared by a new method involving electronic heating, and the formulation is used hot (80 to 100 C.). After casting, the plastic films were aged for two weeks at room temperature to allow the escape of solvents. Dumbbell-shaped specimens 6 in. long (Fig. 1(*c*)), having a constriction $\frac{1}{2}$ in. wide and 2 in. long, were cut from the cast films with a metal die (4). The specimens were then conditioned at room temperature for an additional two weeks prior to exposure to mold tests.

Method of Inoculation and Incubation

Forty-milliliter portions of mineral salts agar[3] were poured into 16-oz. French square bottles and sterilized at 15 lb. pressure for 20 min. The dumbbell-shaped specimens were placed individually on the surface of the solidified agar in the bottles (Fig. 1(*a*)). This test method for determining the fungus resistance of plastics and utilizing a mineral salts agar medium without a source of organic carbon has previously been reported (1) as giving accelerated and uniform results. Although the use of fruit jars containing water at the bottom was found to be a good incubation method for protein-bonded cork gaskets (2), this method is of little value for materials less susceptible to fungi, like plastics.

Spore suspensions of the test organism were prepared from 3- to 5-day-old cultures of *Trichoderma* sp. FA 69 growing on Difco potato dextrose agar. The surface growth of the agar slant was raked with a sterile platinum needle and the spore charge deposited into a flask containing glass beads and 25 ml. sterile distilled water. The flasks were agitated to break up spore clumps, and the specimens were inoculated by pipetting 1 ml. of the spore suspension onto the surface of the plastic strip and the agar medium. After capping the bottles with ordinary screw caps, they were incubated for 6 weeks in a constant-temperature room maintained at 29.0 ± 1 C.

[3] K_2HPO_4...0.7 g.
KH_2PO_4...0.7 g.
$MgSO_4 \cdot 7H_2O$ .....0.7 g.
NH_4NO_3..1.0 g.
NaCl.....0.005 g.
pH of autoclaved medium = 6.4
$FeSO_4 \cdot 7H_2O$. 0.002 g.
$ZnSO_4 \cdot 7H_2O$. 0.002 g.
$MnSO_4 \cdot H_2O$. 0.001 g.
Agar (Difco) 15.0 g.
Distilled water 1000.0 ml.

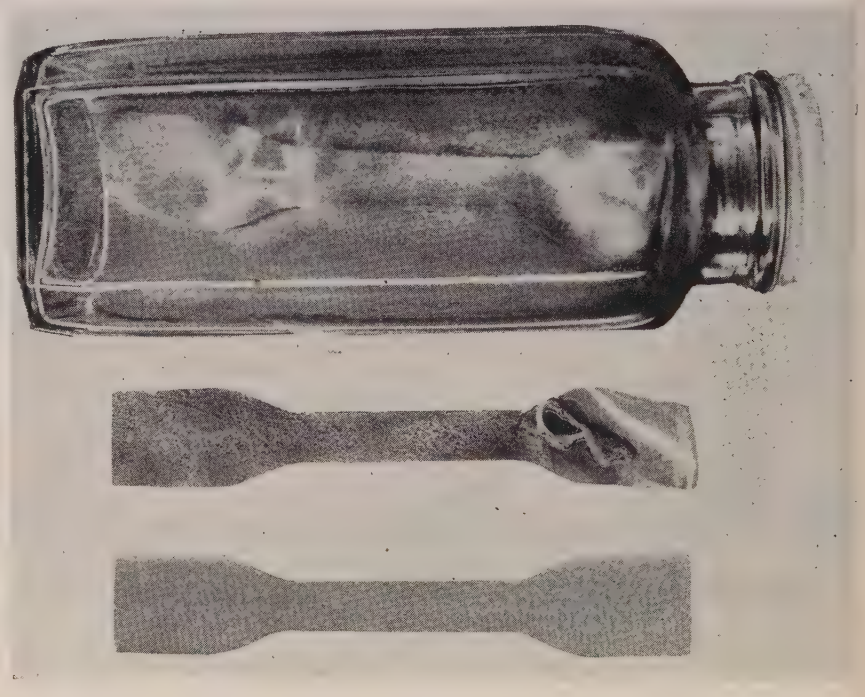

Fig. 1.—Heavy Growth of *Trichoderma* sp. on Specimen of Polyvinyl Chloride Film Plasticized with a Mixture of Dibutyl Sebacate and Dioctyl Phthalate and Incubated on Mineral Salts Agar in a Square Bottle for Three Weeks (*a*). Unincubated Dumbbell Specimen (*c*), and Specimen Covered with a Continuous Fungus Mat after Removal from Bottle (*b*).

Susceptibility of the Plastics to *Trichoderma* sp.

Table II lists the susceptibility of the three plastic formulations to attack by *Trichoderma* sp. after 6 weeks' incubation. Maximum mold growth on the films subject to fungus growth appeared after a two-week period of incubation, Figure 1(*b*) shows that the film plasticized with a mixture of dibutyl sebacate and dioctyl phthalate (formulation No. 1) was covered with a dense fungus mat after 3 weeks' incubation. The substitution of dioctyl phthalate for the dibutyl sebacate in formulation No. 1 increased the resistance of the film to mold attack. This indicates that dibutyl sebacate is extremely vulnerable to fungus growth even when in combination with a mold inert plasticizer (5, 10) like dioctyl phthalate. The National Bureau of Standards reported (10) that pure polyvinyl chloride is not susceptible to mold growth. Any mold that did grow on the plastic must therefore be attributed either to the other components of the plastic or to the combination of the resin with the components.

TABLE II.—EFFECT OF MOLD GROWTH ON THE TENSILE STRENGTH AND PERCENTAGE ELONGATION OF POLYVINYL CHLORIDE FILMS PLASTICIZED WITH THREE PLASTICIZERS.

Plastic films were inoculated with *Trichoderma* sp. FA 69 and incubated at 29.0 ± 1 C. for 6 weeks on mineral salts agar.

Formulation	Number of Specimens	Range in Thickness, mils[a]	Extent of Mold Growth	Mean Tensile Strength, psi.	σ	Per Cent Change in Tensile Strength over Control	Mean Per Cent Elongation	σ	Per Cent Change in Per Cent Elongation over Control
No. 1.....	17	5–16	[b]	2119	132	...	343	35	...
No. 1.....	18	5–26	Moderate to very heavy	3463	1883	+63[c]	113	103	−67[c]
No. 1.....	17	11–18	[d]None to heavy	1834	601	−14[e]	281	41	−18[c]
No. 2.....	15	10–29	[b]	2264	155	...	362	23	...
No. 2.....	15	13–28	None to slight	2125	197	−6[f]	344	46	−5[e]
No. 3.....	15	10–22	[b]	1841	203	...	470	38	...
No. 3.....	15	11–21	None to very slight	2023	197	+10[f]	473	47	+0.7[e]

[a] Thicknesses are those for specimens before exposure to mold growth.
[b] Controls (not incubated).
[c] Increase or decrease is significant at $P = 0.01$ level.
[d] The samples were not inoculated but incubated with paraformaldehyde; 12 samples had no visible mold growth.
[e] Increase or decrease is not significant at $P = 0.05$ level.
[f] Increase or decrease is significant at $P = 0.05$ level.

The films plasticized with 100 per cent dioctyl phthalate or butadiene-acrylonitrile had such little mold growth that they may be considered mold inert.

No data on the fungus susceptibility of the butadiene-acrylonitrile plasticizer were available. The three pure plasticizers were therefore evaluated for susceptibility to *Trichoderma* sp. After 5 weeks' incubation on mineral salts agar in Petri dishes, the dioctyl phthalate showed no growth, the butadiene-acrylonitrile had slight growth, while the dibutyl sebacate was completely covered with mold growth.

Effect of Fungus Growth on Tensile Strength and Percentage Elongation

At the end of the six weeks' incubation period the dumbbell-specimens were removed from the bottles, dipped in a 0.1 per cent aqueous solution of mercuric chloride for 2 to 3 min., rinsed in tap water, and dried at room temperature for 24 hr. The plastic films were then conditioned for 48 hr. at 25 ± 1 C. and 50 ± 2 per cent relative humidity. The tensile strength and percentage elongation of the controls and incubated specimens were determined with a pendulum-type motor-driven Scott Tester (4).

Table II lists the mean tensile strengths and percentage elongations of the unincubated and incubated plastic specimens. Formulation No. 1 containing dibutyl sebacate as one of the plasticizers and inoculated with the fungus had a 63 per cent increase in tensile strength and a 67 per cent loss in percentage elongation over the unincubated controls. Based on Student's t table, this gain and loss is significant at the 0.01 level. The other two formulations had no appreciable changes in the tensile strength or percentage elongation.

Reed and Connor (8) reported that plasticizer loss from nonrigid vinyl chloride - acetate films may occur not only through volatilization but also by extraction by various media with which the film may be brought into contact. The preparation of plastic films with plasticizers labeled with radioisotopes, such as C_{14}, would offer a ready means for determining the amount of plasticizer loss to the mineral salts medium and the amount removed by the fungus. However, since equipment for radioisotope work was not available at the time, the following test was made to determine whether the method used to incubate the plastics in contact with the mineral salts agar, but in the absence of any mold growth, had an effect on the leaching of the plasticizer from the films.

Dumbbell specimens of formulation No. 1 were incubated on mineral salts agar and a pellet (approximately 0.13 g.) of paraformaldehyde, a volatile fungicide, was placed in a 10-ml. beaker and added to each bottle containing the uninoculated plastics. At the end of the incubation period (6 weeks) it was found that the fungicide was not completely effective in inhibiting the growth of contaminating molds present on the plastics. Table II shows that incubating the specimens in the presence of paraformaldehyde did not produce an increase in the mean tensile strength or a large decrease in the mean percentage elongation.

The large increase in tensile strength and loss in percentage elongation of formulation No. 1 containing dibutyl sebacate is attributed to the destruction or removal of the plasticizer by the species of *Trichoderma*. Tensile strength and percentage elongation measurements may therefore be used as a criterion for determining the deterioration of plastics containing mold susceptible plasticizers.

Acknowledgments:

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References

(1) S. Berk, "Evaluation of Test Methods for Fungus Resistance of Non-Rigid Synthetic Electrical Insulating Materials," *Frankford Arsenal Report No. R-921*, Pitman-Dunn Laboratory, October, 1949.
(2) S. Berk, "Fungicides for Fungus-Proofing Glue-Glycerol-Bonded Cork Gaskets," *Industrial and Engineering Chemistry*, Vol. 40, No. 2, February, 1948, pp. 262–267.
(3) J. T. Blake and D. W. Kitchin, "Effect of Soil Microorganisms on Rubber Insulation," *Industrial and Engineering Chemistry*, Vol. 41, No. 8, August, 1949, pp. 1633–1641.
(4) "Rubber Goods; General Specifications (Methods of Physical Tests and Chemical Analyses)," Federal Specification ZZ-R-601a, June 25, 1940.
(5) J. V. Harvey and F. A. Meloro, "Studies on Degradation of Plastic Films by Fungi and Bacteria," *Microbiology Series Report No. 15*, Quartermaster General Laboratories, August 15, 1949.
(6) J. Leutritz, "The Effect of Fungi and Humidity on Plastics," ASTM Bulletin, No. 152, May, 1948, p. 88 (TP 140).
(7) J. Leutritz and D. B. Herrmann, "The Effect of High Humidity and Fungi on the Insulation Resistance of Plastics," ASTM Bulletin, No. 138, January, 1946, p. 25.
(8) M. C. Reed and L. Connor, "Behavior of Plasticizers in Vinyl Chloride-Acetate Resins," *Industrial and Engineering Chemistry*, Vol. 40, No. 8, August, 1948, pp. 1414–1422.
(9) J. L. Stief and J. J. Boyle, "Effect of Fungicides on Natural and Synthetic Rubber," *Industrial and Engineering Chemistry*, Vol. 39, No. 9, September, 1947, pp. 1136–1138.
(10) Summary Technical Report of the Tropical Administration Committee, NDRC, "Tropical Deterioration of Equipment and Materials," Vol. 1, Chapter 5, 1946.

Laboratory Testing of the Rain Erosion Resistance of Aircraft Finishes[1]

By Jack K. Grace[2] and George C. Frey[2]

Synopsis

Erosion has occurred on the surfaces of several modern airplanes during flight through rain. The eroded areas have been principally the surfaces of low-pressure, glass cloth-polyester laminates, and organic finishing materials.

Test equipment has been principally of two types: water-jet testers and whirling arm testers. The water-jet testers operate by impinging a high-velocity jet of water on a specimen. The jet is usually modulated or interrupted in some manner. The whirling arm testers move the specimen, at high speed, through a water spray simulating rain. Erosion somewhat similar in appearance to that obtained in service is obtained with both types of testers.

In this paper, data from a jet-type tester are compared with previously reported data from a whirling arm tester. Both sets of data indicate that the time required for erosion failure of several plastic materials varies as the reciprocal of a large power of the velocity. The specific relation, however, differs greatly for the two testers, the velocity exponent being approximately 18 for the jet tester and 7 for the whirling arm tester.

Certain plastic laminate configurations and certain organic finishes show markedly better rain erosion resistance in tests than do conventional laminates and finishes.

One of the first reported cases of serious rain erosion on airplane parts occurred in the Summer of 1945, in the Pacific war area, when the Air Force encountered extensive deterioration of a new type laminated plastic radar housing after long operational flights involving rain. This deterioration of the radar housing, known as the Eagle wing installation, was subsequently described by Robertson, Lobisser, and Stein (1).[3] A few hours of flight in rain resulted in several layers of the glass cloth and resin laminate being worn away, leaving an eroded appearance described as similar to the effect of sand blasting.

Erosion of exterior surfaces of aircraft by flight through rain has been increasingly prevalent on military aircraft of recent design. The severity of the erosion has increased with the greater flight speeds currently used, and the seriousness of the problem has grown with the increased use of laminated plastic parts on the exterior of airplanes.

The erosive effect of rain on high-speed airplanes has not been limited to plastic surfaces. Conventional organic finishes have been eroded from the leading edges of painted airplanes. Extensive removal of finish was experienced on painted night fighters in 1944, and investigations of the resistance of finishes to air-water blasts were reported by Hawley (2). A satisfactory solution to one phase of the erosion problem might well be a solution to other phases; however, most of the work reported to date on the rain erosion of aircraft has dealt with the erosion of laminated plastic surfaces and of protective coatings applied to these surfaces.

Materials Involved

Laminated plastic parts are currently used on the exterior of airplanes for three principal reasons: minimum absorption or attenuation of radio and radar signals, ease of fabrication in complex shapes, and economy of production. It is essential that aircraft radio and radar antennas be placed in housings which maintain the smooth contours of the airplane and do not interfere with the functioning of the antenna. Antenna housings, which formerly were frequently auxiliary attachments, now are found in such integral parts of the airplane as the nose, wing tips and empennage tips, and the leading edges of wings and empennage surfaces.

Frequently, since radio and radar communication is usually desired in a forward direction, these housings present some frontal area. These frontal areas represent areas of possible impact and erosion during flight.

In addition to antenna housings, laminated plastic parts are frequently used in areas of difficult contour where metal parts would be more difficult and more expensive to fabricate. Parts such as fairings and wing tips are frequently in this category.

Laminated plastic parts used on the exterior of airplanes are principally of the glass cloth - polyester resin type. The glass cloths used range from 4 to 10 oz. per sq. yd. in weight. Glass cloth is used in preference to other fabrics to obtain a combination of high strength and moisture resistance, and long service life. The resins used are alkyds such as glycerol phthalates modified with an unsaturated hydrocarbon such as styrene. These polyester resins are of the low-pressure type, requiring a minimum of pressure during cure. This characteristic is particularly advantageous in manufacturing relatively small numbers of parts of complex shape with a practical minimum of tooling. The resins are cured with catalysts at temperatures of 200 to 300 F.

The completed laminates range from $\frac{3}{64}$ to $\frac{1}{8}$ in. in thickness and have an average resin content of 35 to 40 per cent. Where greater stiffness is required than can be obtained conveniently with a simple laminate, sandwich type structures are used. These consist of some type of lightweight core material such as a resin foam or a resin impregnated glass cloth honeycomb sandwiched between two glass cloth-polyester resin laminates.

The exterior surface of the laminated part may have the normal fabric weave pattern of the outer layer of fabric. Frequently, however, special treatment is given the exterior surface of the part for improved aerodynamic smoothness, improved appearance, or improved abrasion resistance. The surface may be made smoother by increasing the resin content of the outer ply or by using finer weave cloth. A special technique has also been developed for molding the part with an integral resin overlay approximately 0.015 in. thick. This overlay is often referred to as a gelled resin overlay because it is applied to the mold as a gelled resin prior to laying up the cloth laminates. This resin coating may be dyed or pigmented to obtain a desired finish color to match the exterior of the airplane. When necessary, the exterior of laminated plastic parts may be painted with conventional organic

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NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] This paper was presented at the Session on Paint held at the First Pacific Area National Meeting of the Society, San Francisco, Calif., October 10–14, 1949.

[2] North American Aviation, Inc., Los Angeles, Calif.

[3] The boldface numbers in parentheses refer to the list of references appended to this paper.

Fig. 1.—Typical Rain Erosion Failure.

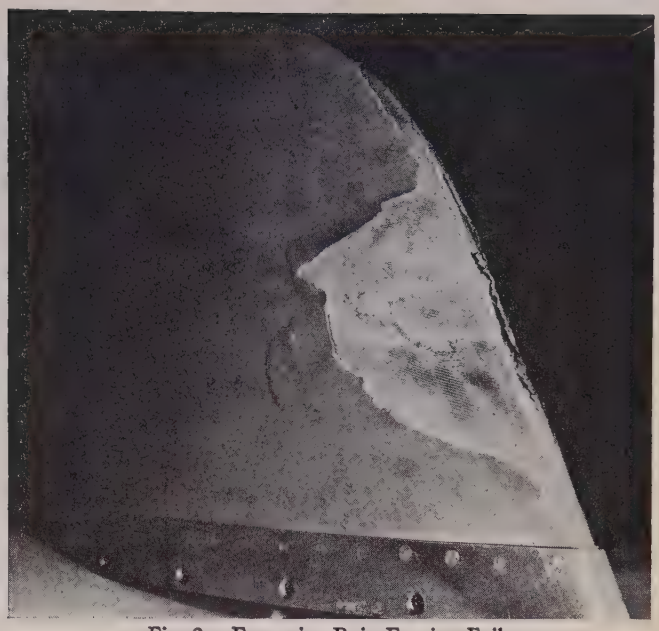

Fig. 2.—Excessive Rain Erosion Failure.

nishing materials, including surfacing naterials when smoothness or contouring is critical.

As mentioned previously, rain erosion as also been observed on the organic nish of nonplastic exterior surfaces of irplanes. Currently, many types of irplanes are not painted except for insignia and markings so that erosion of nish is not a universal problem; however, most Naval airplanes are painted a lossy sea-blue color and certain fighter lanes are painted glossy black. Aircraft acquers are generally used for these olor applications, although enamels ave been used to some extent recently o obtain additional resistance to normal amage. Special protective finishes are eing applied to certain airplanes specifically for rain erosion resistance. hese finishes range from tough rubberke materials to a baked phenolic varish and, for the most part, are being pplied as experimental or intermediate evelopment phases of rain erosion investigation programs.

Service Failures

A detailed examination of the rain rosion problem from the standpoint of ervice failures is difficult because of the mited number of failures reported. In eacetime flying, rain is avoided when ossible because of the air turbulence sually accompanying rain storms. or this same reason and because visiility is seriously impaired when flying hrough rain, severe storms with heavy recipitation are avoided when practiable in military operations as well.

In the case of the Eagle wing, previusly mentioned, severe erosion was obained during flight through rain at speeds presumably in the neighborhood of 300 mph. The erosion was reported (1) as taking place in an uneven manner along the leading edge. Subsequently, rain erosion has been reported principally on fighter type airplanes. Erosion has been reported on laminated plastic parts after 30 sec. to 5 min. flight through rain at speeds of from 300 to 400 mph. Erosion has been limited to the extreme leading edges of parts within a narrow band and has been principally of a spotty irregular nature, presumably in areas of relative weakness in the laminates. Figures 1 and 2 show typical rain erosion on representative laminated plastic parts from fighter airplanes. It should be noted that the trend in fighter airplanes appears to be to higher speeds, approaching and possibly exceeding sonic speeds. As can be observed qualitatively from the experience above and as evidenced in tests described below, rain erosion tendencies can be expected to be much more severe at these higher speeds.

Other Causes of Erosion

When the Eagle wing erosion was first reported, it was expected, as reported by Callaghan (3), that the erosion might have been caused at least in part by chemical action of fumes in the engine exhaust gas. Preliminary tests, however, showed that water impingement alone could cause similar erosion, and subsequent erosion on the leading edges of jet engine aircraft has made chemical action seem less probable.

Sand and dust particles can also cause erosion, as evidenced by the wear on propeller blades and the under surfaces of airplanes, particularly when using unpaved runways. Erosion in flights predominantly over the ocean as in the Pacific operations with the Eagle wing, and in flights at appreciable altitudes, have dispelled dust as being a probable cause of the observed erosion. It should be mentioned that hail and ice particles appear to be probable sources of erosion, possibly considerably more severe than rain. While these particles are not considered to have been present in most of the cases of rain erosion reported, erosion from this source may be a serious future problem. So far as is known, no investigations have been reported on ice erosion of airplanes.

A possible contributing factor to rain erosion failure is the deterioration of the surface of the parts as a result of exposure to normal service conditions. Some of these factors are sunlight and moisture, extreme cycles of temperature from 160 F. to −65 F., and flexing and vibration. All of these factors may cause roughening or crazing of the surfaces of both laminated plastic parts and organic finishes with probable increase in the tendency to erode in rain.

Nature of Rain

Considerable data are available on the size, distribution, and velocity of raindrops. Humphreys (4) gives a range of drop sizes, as shown in Table I, for various types of precipitation. These values are generally accepted by other authorities. Berry, Bollay, and Beers (5) give a more detailed distribution of raindrop sizes as shown in part in Table II.

From these data it appears that falling raindrops are predominantly in the size range of 0.5 to 2 mm. in diameter, considering the drops as spheres. These

TABLE I.—PRECIPITATION VALUES.
(Air Density as at 0 C. Temperature and 740-mm. Pressure.)

Type of Precipitation	Precipitation Intensity, in. per hr. (Converted from mm. per hr.)	Diameter of Drop, mm.
Fog	Trace	0.01
Mist	0.002	0.1
Drizzle	0.010	0.2
Light rain	0.040	0.45
Moderate rain	0.15	1.0
Heavy rain	0.6	1.5
Excessive rain	1.5	2.1
Cloudburst	4 to 40 (?)	3.0

TABLE II.—DISTRIBUTION OF RAINDROP SIZES.

Drop Diameter, mm.	Number of Drops Caught per sq. meter per sec.		
	Ordinary Rain	Violent Cloudburst	Heaviest Cloudburst
0.5	1000 to 1600	100	514
1.0	200 to 120	1300	423
1.5	140 to 60	500	359
2.0	140 to 200	200	138
2.5	...	...	156
3.0	...	...	138
4.5	...	200	101
Total Drops	1480 to 1980	2300	1829
Rainfall, in. per hr.	0.14	1.69	1.35

drop sizes are as observed at ground level. Condensed droplets observed in clouds are of considerably smaller magnitude and range from 8 to 50 μ in diameter (6). Since airplanes may fly at very low altitudes, it appears prudent to consider the larger drop sizes in rain erosion investigations.

The velocity of fall of raindrops increases with drop size and is reported as ranging from 4.4 meters per sec. or approximately 10 mph. for 1.0-mm. diameter drops, to a maximum of 9.3 meters per sec. or approximately 21 mph. for 5.5-mm. diameter drops. It can be seen that these velocities are negligible compared to the speeds of modern airplanes, and consequently the velocity of impingement of rain on the frontal area of an airplane will not be appreciably affected by the angle of flight.

In connection with icing investigations, the effect of the air flow over an airfoil surface on the impingement or catch of raindrops has been calculated by Guibert, Janssen, and Robbins (7). The dispersion of drops by the air flow becomes less as the drop size increases and, although the efficiency of catch may be as low as 10 per cent for drop sizes of the order of 10 μ diameter, the efficiency of catch for drop sizes of the order of 1 mm. diameter is substantially 100 per cent.

Related Investigations

Although the effect of rain erosion on high-speed airplanes is a relatively recent subject for investigation, it might be expected that quantitative data would have been obtained and the relation of the several variables established for similar erosion processes such as sand blasting. However, as noted recently by Stoker (8), there is little published information of a quantitative nature in these fields. Fisher and Davis investigated the erosion of metals by fly ash produced by burning pulverized coal (9) and showed that erosion increased markedly with increasing velocity. It was also stated that for some conditions erosion appeared to be primarily related to the hardness of material eroded. Stoker investigated the erosion of black iron and cast gypsum plaster. The eroding mediums were silica sand and the dust of two commercial synthetic catalyst materials used in fluid type catalytic cracking plants for petroleum. The catalysts were presumably of the aluminum oxide - silica type. The particles were blown against the specimens with an air jet of controlled velocity ranging from 60 to 600 ft. per sec. For normal impingement of the jet on the specimen, it was observed that the erosion, reported as decrease in weight of the specimen per unit weight of particles used, varied approximately as the cube of the air velocity for the gypsum specimens. The erosion of black iron, reported in the same units, also varied as approximately the cube of the air velocity for velocities of the order of 150 ft. per sec., similar to those used for the gypsum erosion. However, at higher air velocities, not tested with the gypsum, the black iron erosion varied as approximately the $2\frac{1}{2}$ power of the velocity. This reduction in the rate of increase of erosion with higher air velocities was presumably caused by the failure of the heavier particles to achieve the velocity of the air. It was further noted by Stoker that the erosion was approximately twice as fast for the sand as for the catalysts. This was especially true for the smaller catalyst which had particle sizes approximately half that of the sand.

In Stoker's tests, the solid particles were metered into the air stream at a constant rate regardless of the air velocity so that the rate of impingement was independent of the velocity. Thus,

$$m = ft$$

$$\frac{W}{m} = K_1 v^3$$

where:

m = total mass of particles eroding,
f = mass flow rate of eroding particles (constant),
t = elapsed erosion time,
W = wear of specimen, weight loss,
K_1 = proportionality constant, and
v = air velocity, relative velocity of particle and specimen.

In the case of rain impingement in flight, however, the concentration of particles, or drops, can be conveniently considered constant for a given rain condition, and the rate of impingement is therefore directly proportional to the velocity. It is of interest to convert Stoker's data to these conditions for comparison with rain erosion data. Such a conversion is valid for conditions of similar particle type and concentration to that in the original experiment and, it appears, should be valid for any particle concentration in which the particles interact in the same manner as for the test conditions. Thus,

$$m = Ctv$$

$$\frac{W}{t} = KCv^4$$

where:

K = proportionality constant, and
C = particle concentration.

From Stoker's data it appears that K is a function of the characteristics of the material being eroded—possibly the hardness—and of the characteristics of the eroding medium.

The loss of energy, E, due to impact between small particles of mass, M, and a relatively large body is substantially

$$E = \frac{m_1(1 - e^2)(v)^2}{2}$$

where:

e = coefficient of restitution between the materials, and
v = relative velocity of particles and body before impact.

It is evident, therefore, that the erosion wear in Stoker's tests is not directly proportional to the energy loss, as might have been expected.

Early Investigations

To investigate the rain erosion effect and to determine the erosion resistance of various materials, laboratory tests are desirable. Data from these laboratory tests should, if possible, be compared with flight test data to determine if a realistic relation exists. Flight tests are, however, so costly and subject to so many variables difficult to control or even determine that quantitative data from this source will probably not be available for some time. No standard testing methods for simulated rain erosion of fast moving bodies are known. Standard tests for abrasion resistance, such as A.S.T.M. Standards D 658 – 44 and D 968 – 48 T are available,[4] but it is believed that tests more nearly simu-

[4] Methods of Test for Abrasion Resistance of Coatings of Paint, Varnish, Lacquer, and Related Products by the Airblast Abrasion Tester (D 658) and by the Falling Sand Method (D 968), 1949 Book of A.S.T.M. Standards, Part 4, p. 399 and p. 403, respectively.

lating the service conditions are necessary.

Several direct investigations of high velocity water erosion of aircraft materials have been made. Hawley (2) investigated the resistance to water impingement of several aircraft finishes applied to aluminum alloy sheet at the laboratory of Northrop Aircraft. The impingement test was performed by blowing an air-water mixture from a $\frac{3}{16}$-in. diameter mixing nozzle at the specimen spaced 3 in. from the end of the nozzle. No velocity measurements were reported, but since the air pressure was 45 psi. and the water pressure 40 psi. it is believed that the velocity was relatively low. All samples were subjected to 24 or 30 hr. immersion in water prior to the impingement test. Some lacquers and enamels failed after 5 min. impingement while several samples were satisfactory after 30 min. and, in one case, after 90 min. impingement. It was concluded that Specification AN-E-3 type aircraft enamel was hygroscopic and hence failed in the tests. A proprietary enamel was recommended as most satisfactory for use on all-weather night fighter airplanes.

Robertson, Lobisser, and Stein (1) reported tests run on various plastic laminates and several protective coatings at the Radiation Laboratory of the Massachusetts Institute of Technology. Flat panel samples were rotated on a 28-in. streamlined arm at a speed of 260 mph. through a water spray from two commercial spray nozzles. Erosion of a typical glass cloth - polyester resin laminate occurred at the rate of approximately one layer every 5 min. It was reported that while there was a difference in the erosion rate for various polyester and phenolic resins, none could be considered satisfactory. Laminates made with cotton duck had superior erosion resistance. No wear was produced on an acrylic panel or on a $\frac{1}{32}$-in. sheet of rubber cemented to a standard laminate. Rubber coatings built up to a thickness of 0.010 in. gave protection.

Callaghan (3) reported simulated rain erosion tests run on a section of an Eagle wing section with various finishes applied. These tests were run in the icing research tunnel of the Cleveland Research Laboratory of the National Advisory Committee for Aeronautics. A true air speed of 300 mph. was used and raindrops of 0.3 to 0.5 mm. diameter were believed to have been used. The water content of the air varied across the length of the airfoil section tested from 4 to 12 g. per cu. m. The erosion obtained was reported as very similar in appearance to that previously obtained in flight with the Eagle wing. It was concluded that the erosion is dependent upon the air speed, the average size of the water droplets, and the rate of impingement of the drops. It was also noted that the "plastic content" of the surface varied widely and permitted spotty erosion, and it was concluded that rain erosion resistance of uncoated radome surfaces would be greatly increased by a more uniform, bubble-free resin impregnation. One layer of laminate was eroded in 25 min., and five layers were eroded in 195 min., indicating an approximately direct relation between erosion time and severity of erosion. Several proprietary coatings of the chemical resistant type failed in from 5 to 25 min. One of these failed coatings, a chlorinated rubber base paint, was a material reported by Callaghan as having previously shown superior abrasion resistance in tests by the Bell Telephone Laboratory with a calibrated carborundum blast. Another of the failed coatings, a Thiokol base paint, was previously found to show superior rain erosion resistance in tests on the whirling arm tester at the Massachusetts Institute of Technology. A second chlorinated rubber base paint failed in 130 min. A Neoprene coated Nylon fabric with 0.036 in. total thickness of neoprene cemented to the laminate specimen showed no sign of deterioration after 195 min. of testing. The coated fabric was, however, cemented to portions of the airfoil specimen which received air flow with somewhat lower water content than the remainder of the specimen.

Gibbud (10) reported tests run on various materials, principally fabric-resin laminates, using an 0.040-in. water nozzle ejecting water from a single piston reciprocating pump at a maximum velocity of 105 mph. at specimens spaced 2 in. from the nozzle. This work was performed at the research laboratory of the Owens-Corning Fiberglas Corp. Because of the pump action a half wave sinusoidal pressure wave was assumed to have been obtained. In general, conventional glass cloth - polyester resin laminates did not have adequate erosion resistance, failing in from 30 min. to 3 hr. Several laminates made with higher pressure showed satisfactory erosion resistance, and two laminates made with a mixture of a thermosetting resin and an acrylic resin in one case and the thermosetting resin and a vinyl resin in the other were also considered satisfactory. The satisfactory materials showed only surface scarring after 14-hr. exposure and were reported as comparable in erosion resistance to aluminum alloy.

Fig. 3.—Whirling Arm Tester—Cornell Aeronautical Laboratory.

Recent Investigations

Recent laboratory investigations have centered around two types of testers similar in principle to those used in earlier investigations. These two types are the whirling arm tester and the water jet tester.

The whirling arm testers are similar in principle to the tester originally constructed at the Massachusetts Institute of Technology, with modifications to increase the speed of travel and more accurately to simulate raindrops. Testers of this type can be made to simulate service conditions very closely. Several testers of the whirling arm type have been or are being investigated under the auspices of the United States Air Force and Navy Bureau of Aeronautics.

The jet type testers are similar in principle to the Owens-Corning Fiberglas tester, with modifications to increase the jet velocity and to break the jet flow into smaller individual volumes of water to more nearly simulate raindrops. Testers of this type are simpler to construct and present less potential hazard to personnel in operation, but their ability to reproduce service conditions has yet to be proved. Several testers of this type have been constructed, including one at Lockheed Aircraft Corp. (11).

Extensive work on simulated rain erosion testing has been done and is currently in progress at the Cornell Aeronautical Laboratory under contract from the U. S. Air Force. A whirling

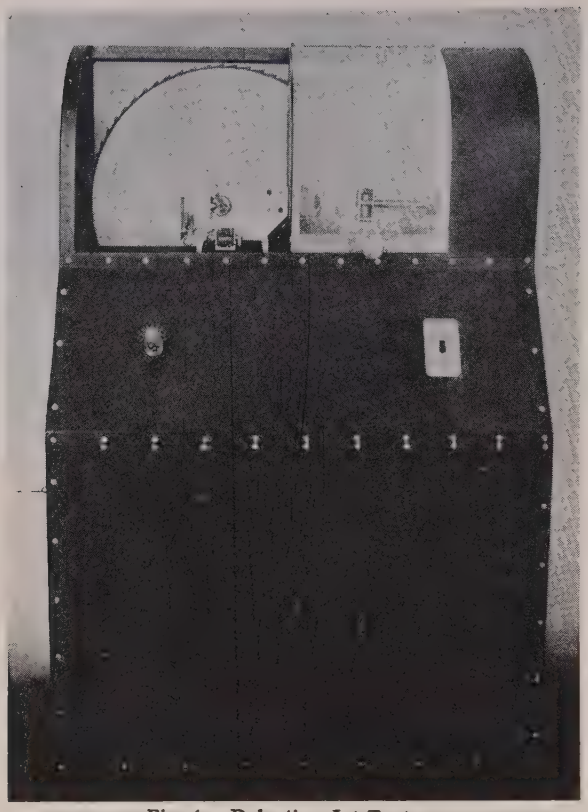

Fig. 4.—Pulsating Jet Tester.

arm type tester was designed and constructed. A description of the tester and preliminary tests has been reported (12). The tester, illustrated in Fig. 3, was designed to attain controlled speeds up to a maximum of 700 mph. A standard airfoil section was used for the 24-in. blade of the tester. Raindrops of 1.9 mm. diameter with an equivalent rainfall of 1 in. per hr. and 2.5 mm. diameter with an equivalent rainfall of 3 in. per hr. are used. Specimens are molded to the contour of the leading edge of the airfoil. It was concluded that the air movement caused by the whirling blades did not appreciably affect the raindrop fall pattern.

Erosion similar to rain erosion obtained in flight was obtained on plastic specimens in the Cornell tester. The extent of erosion of the specimens is noted at intervals during the tests. An attempt to report the rate of erosion quantitatively by weight loss was reported as unsuccessful, because of the large pieces of glass fibers and resin which were removed at intervals during the erosion. No quantitative relations were determined, but it was concluded that the rate of erosion increases with velocity and raindrop size and is not affected by temperature in the range from 4 C. to 30 C. Under standardized conditions of 250 mph. and 1.9-mm. drops it was concluded that there was no appreciable difference in the erosion rate of various polyester resins and glass fabrics used in laminates, but that cotton cloth - polyester resin laminates had much improved erosion resistance. An outer ply of 0.010 in. thick polyethylene sheet showed only very slight erosion after 24 hr. testing at 300 mph., compared to severe erosion after 10 to 90 min. for conventional glass cloth laminates.

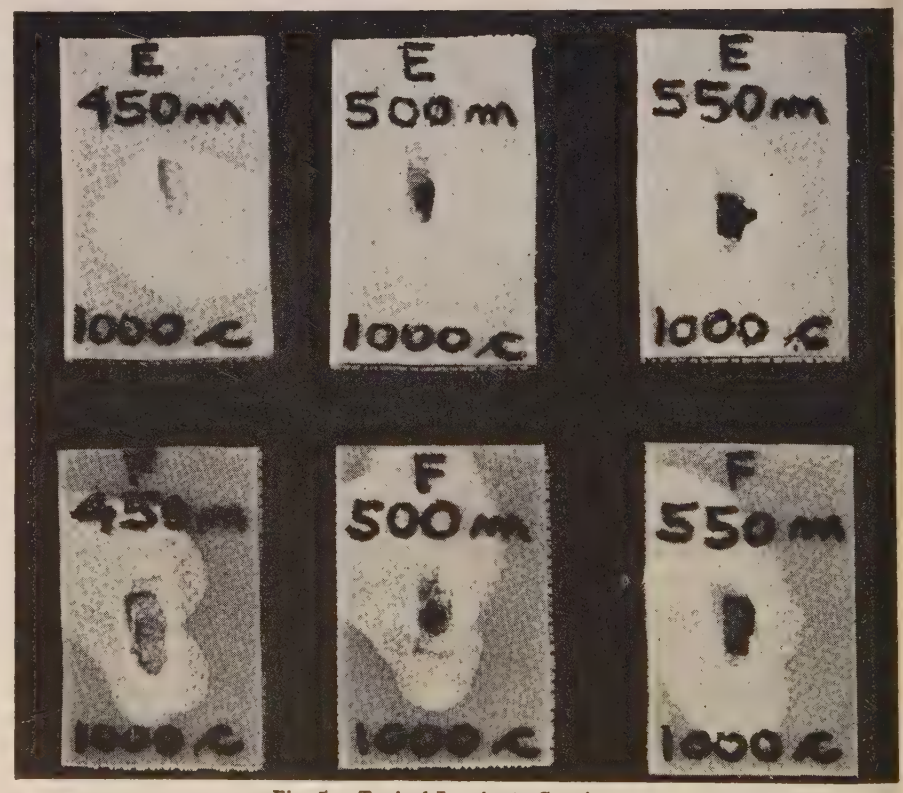

Fig. 5.—Typical Laminate Specimen.

Test Equipment and Procedure

A water-jet rain-impingement tester was constructed in the Engineering Research Laboratory of North American Aviation in 1947 and was used for testing erosion resistance from that time until May, 1949. This tester was of the pulsating-jet type and produced an intermittent high-velocity water jet of 0.026 in. diameter by means of a reciprocating pump. The pump was valved so that the high-velocity portion of the jet was developed during only a small portion of the cycle. The velocity of the jet stream was varied by changing the speed of the pump. The jet velocity was measured by directing the stream against an impingement dynamometer consisting of a cantilever beam to which a strain gage was fixed. By this means the instantaneous impact force of the stream could be measured and the instantaneous velocity of the stream calculated. Figure 4 illustrates the pulsating-jet tester. Tests were conducted by impinging the water-jet stream against the surface of the particular material or coating to be tested and measuring the number of pulses of the interrupted water stream required to cause failure. Finishes were considered to have failed when the base material had been exposed. Homogeneous materials were considered to have failed when a 0.005-in. deep hole, measured with a needle point mounted on a dial gage, had been bored in the surface, and

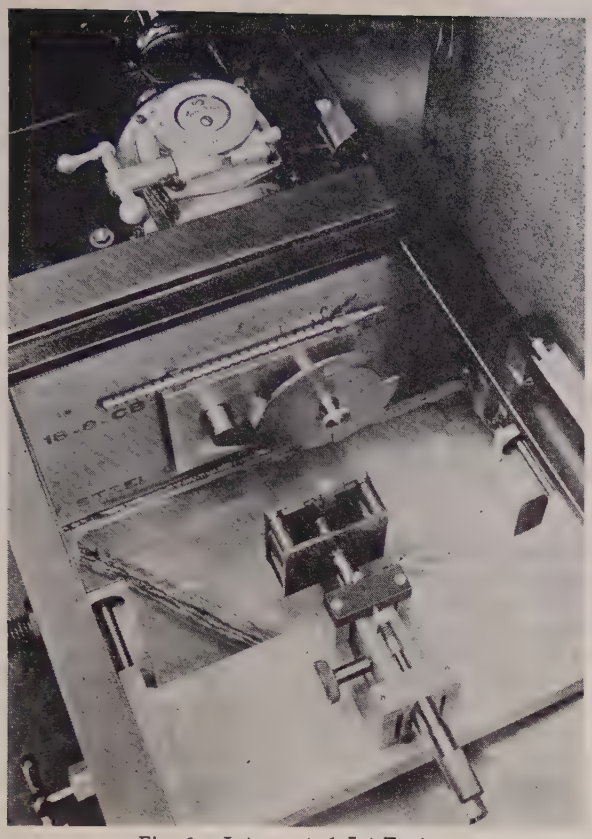

Fig. 6.—Interrupted-Jet Tester.

Fiberglas cloth laminates when the first layer of cloth had been penetrated. Figure 5 shows typical tested specimens of plastic laminates.

During initial testing, materials eroded by the pulsating-jet tester have a similar appearance to flight-test rain-eroded materials. However, as the testing progresses the jet stream bores a hole in the specimen and builds up hydraulic pressure within it which usually causes delamination. At this stage the specimen does not appreciably resemble actual rain-eroded materials.

Extensive use of the pulsating-jet tester indicated that small leaks in the high-pressure system, such as leaks past the piston of the pump, lowered the water pressure and consequently reduced the water-jet velocity for a given water pump speed. Following prolonged usage of this tester the water-jet velocity was found to be substantially less for the same pump speed. An investigation showed that this decreased velocity had resulted from wear in the pump. Attempts were made to compensate for the reduced pressure resulting from this leakage by increasing the water pump speed, but this procedure was found to be unsatisfactory since the total quantity of water discharged from the nozzle during each individual jet pulse was less even though the water-jet velocity had been increased to its former value.

In view of the variation in the performance of the pulsating-jet tester, it was decided to construct a second tester which would employ a constant pressure continuous-flow pump and would, therefore, not be subject to this particular functional variation.

This second rain-erosion tester produces a continuous 0.020-in. diameter high-velocity jet stream of water to which the various test materials are subjected. A 10-hp. positive-displacement continuous-flow pump provides the pressure necessary to produce the jet. A rotating slotted disk is used to interrupt the jet to produce individual pulses of water of the desired mass. The pulse length and mass can be varied either by changing the rotational velocity of the disk or the width of the slots in the disk.

TABLE III.—RELATIVE RAIN EROSION RESISTANCE OF MATERIALS AS TESTED ON PULSATING-JET TESTER.

	Appearance of Samples After Testing (N—No Erosion; SE—Slight Erosion; F—Eroded to Failure)											
Jet velocity	450 mph.			500 mph.			550 mph.			600 mph.		
Number of water impingement cycles	10	10^2	10^3	10	10^2	10^3	10	10^2	10^3	10	10^2	10^3
1. Glass cloth-polyester resin laminate	N	N	N	N	F	F	..	F	F	N	F	F
2. Same as 1, except lighter weight glass cloth	..	..	N	..	..	F	..	..	F	N	F	F
3. Same as 1, except 25 per cent flexible resin in surface ply	N	N	N	..	..	F	..	..	F	N	F	F
4. Same as 2, except 25 per cent flexible resin in surface ply	..	..	F	..	..	F	..	..	F	F	F	F
5. Glass cloth-polyester resin laminate with clear gelled resin overlay	N	N	N	N	N	N	N	N	N	N	..	F
6. Glass cloth-polyester resin laminate with pigmented gelled resin overlay	N	N	N	N	N	N	N	N	F	N	..	F
7. Glass cloth-polyester resin laminate with gelled resin overlay containing 50 per cent flexible resin	N	N	N	..	..	F	..	..	F	F	F	F
8. Glass cloth-polyester resin laminate with gelled resin overlay containing 5 per cent milled glass fibers	N	N	N	N	N	N	N	N	N	N	N	F
9. Glass cloth-polyester resin laminate	N	N	N	N	N	F	N	N	F	N	N	F
10. Paper base-melamine resin high-pressure laminate	..	..	..	..	..	..	N	N	N	..	..	..
11. Paper base-phenolic resin high-pressure laminate	..	..	..	..	..	..	N	N	SE	..	..	..
12. Cotton cloth-phenolic resin high-pressure laminate	..	..	..	..	..	..	N	N	SE	..	..	..
13. Methyl methacrylate plastic sheet, ¼ in. thick	N	N	N	N	N	N	N	N	N	N	N	F
14. Nitrocellulose lacquer, two coats over aluminum	..	..	..	N	N	F	N	F	F	..	..	F
15. Nitrocellulose lacquer, two coats on laminate	..	..	..	..	..	..	..	..	..	F	F	F
16. Special pigmented vinyl finish, 5 coats over aluminum	..	..	..	N	N	F	N	N	F	..	..	F
17. Phenolic base coating, 3 coats, baked at 400 F., over laminate	N	N	N	N	N	N	N	N	N	N	N	F
18. Phenolic base coating, 3 coats, baked at 400 F., over gelled resin overlay	N	N	N	N	N	N	N	N	N	N	N	N
19. Alkyd-melamine base coating, 3 coats, baked at 300 F., over gelled resin overlay	..	..	..	N	N	SE	N	N	F	N	N	F
20. Epichlorhydrin base coating, 3 coats, baked at 300 F. over gelled resin overlay	..	..	..	N	N	F	N	N	F	N	F	F
21. Alkyd-urea base coating, 3 coats, baked at 275 F. over gelled resin overlay	..	..	..	N	N	N	N	N	SE	N	N	F
22. Styrenated alkyd base coating, 3 coats baked at 400 F. over gelled resin overlay	..	..	..	N	N	F	N	N	F	N	F	F
23. Clear vinyl coating, 10 coats, air dry, over laminate	..	..	..	..	..	..	..	..	..	..	..	F[a]
24. Vinyl-thiokol coating, 4 coats, over laminate	..	..	..	..	..	..	..	..	..	..	..	F[a]
25. Polyvinylchloride film, over laminate	..	..	..	..	..	..	..	..	..	..	..	F[a]
26. Neoprene coating, two coats, baked at 240 F., over laminate	F	F	F	F	F	F	F	F	F	F	F	F
27. Chlorinated rubber modified synthetic enamel, 4 coats, over laminate	..	..	..	..	..	..	..	..	..	..	..	F[a]

[a] Tested only at 200 cycles—no observation made before 200 cycles.

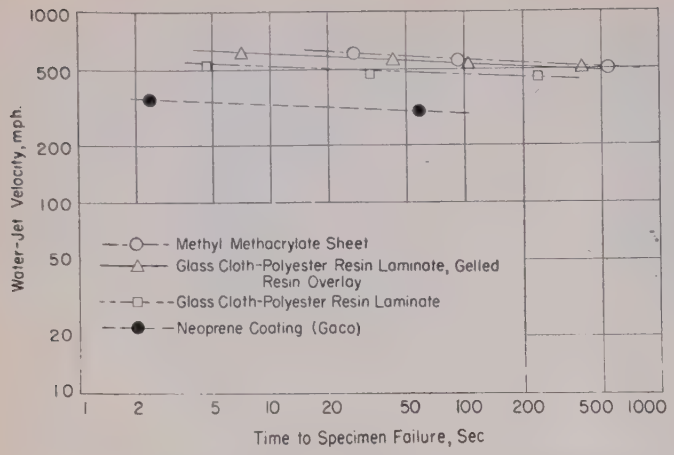

Fig. 7.—Relative Rain-Erosion Resistance of Several Materials as Indicated by a Pulsating-Jet Tester.

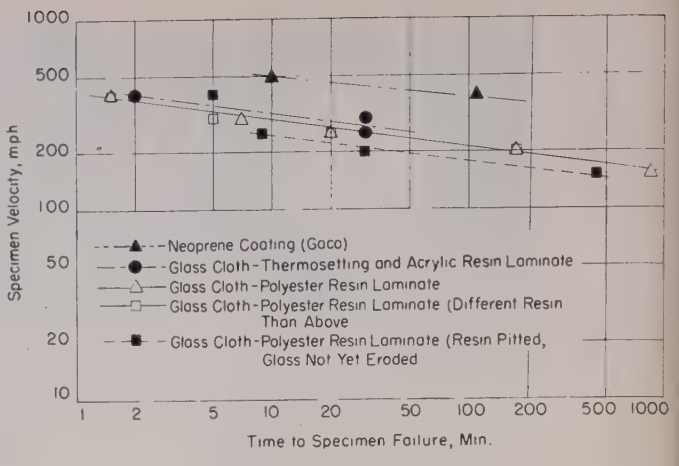

Fig. 8.—Relative Rain-Erosion Resistance of Several Materials as Indicated by a Whirling-Arm Tester.

This interrupted-jet tester (Fig. 6) is similar to the Lockheed Aircraft Tester (11), with certain modifications, including an automatic timer. The automatic timer consists of an impingement dynamometer similar to the one used to determine the instantaneous water-jet velocity of the pulsating-jet tester. The specimen holder is incorporated into the dynamometer so that the impact force of the jet stream against the specimen can be measured. The automatic timer operates on the principle that the force exerted on a flat surface by a water jet is less than the force exerted by the same jet on a concave surface. Experiments show that the impingement dynamometer will indicate change in force when a hole as shallow as several thousandths of an inch is eroded in the surface of a flat test specimen. This dynamometer is connected to electric actuators which stop the timer and interrupt the water jet as soon as an increase in force occurs.

At the time of the original preparation of this paper, the interrupted-jet tester had not been adequately calibrated to conduct detailed erosion tests. Because of the reproducibility of results and flexibility of operating variables which are features of the use of this tester it is expected that the interrupted-jet tester can be adjusted to give erosion results directly comparable to flight erosion.

Test Results

With the pulsating-jet tests two different methods were used to evaluate the comparative water-jet erosion resistances of test materials. In the first method specimens of different materials were subjected to a series of erosion tests wherein each specimen was subjected to an arbitrarily selected number of water-jet impingement cycles at an arbitrarily selected jet velocity. The relative erosion resistances of the test materials were then estimated by visual comparison of the eroded specimens. This method of evaluation was simple and fast, but it failed to reveal slight differences in the erosion resistance of materials, and it did not give a numerical value for the erosion resistance.

A second test method was therefore established in which the number of jet impingement cycles to cause specimen failure was determined for various water-jet velocities. These data were converted for plotting by multiplying the impingement cycles by the cycling rate of the tester to obtain the time required for erosion failure of the specimen. This latter method of testing was difficult to use since it was necessary to stop the tester frequently in order to determine the extent of erosion and the impingement cycles necessary to cause failure. With certain of the materials tested, erosion failure was evidenced by an abrupt change in the angle at which the water jet splashed off the specimen surface, but even in such cases, it was difficult to determine accurately the number of water-jet impingement cycles necessary to produce exactly the same degree of erosion in different specimens. The automatic timer on the new interrupted-jet tester should make testing by the second method much easier and more precise.

Data are given in Table III for tests conducted with the pulsating-jet tester on several materials and protective coatings. These data were obtained by the first method of test and specimens were, for the most part, examined after 10, 100, and 1000 cycles of erosion at jet velocities of 450 to 600 mph.

In general, these data indicate that a gelled resin overlay considerably improves the erosion resistance of conventional polyester laminates and that adding a flexible resin to either the resin overlay or the basic laminate does not improve the erosion resistance. It also appears that harder, more uniform laminates, such as high-pressure phenolic and melamine laminates, have much better erosion resistance than conventional low-pressure polyester laminates. Conventional finishing materials gave no appreciable protection from erosion, but several special materials showed promise of giving protection. These finishes were all of the harder types.

In Fig. 7, data obtained by the second method of testing are plotted on full logarithmic paper, showing the time required to produce erosion failure in several materials at various water-jet velocities using the pulsating-jet tester. Straight lines, approximately parallel for each material, can be drawn for these data, indicating a relation approximately as follows:

$$t = \frac{K}{v^{18}}$$

where:

t = erosion time to failure,
v = velocity of water jet, and
K = proportionality constant.

Although the term "rate of erosion" is of questionable meaning for nonhomogenous materials such as laminates where deterioration appears to occur at a nonlinear rate, the above equation may be written as follows for comparison with Stoker's erosion data:

$$\frac{1}{t} = Kv^{18}$$

Data giving the time of testing for similar conditions of erosion at several velocities for some materials tested on the whirling arm tester at Cornell Aeronautical Laboratories were also plotted on full logarithmic paper in Fig. 8. In examining the data given in Fig. 8, consideration should be given to the statement in the source from which most of the data were taken that these data are of necessity only roughly quantitative since no satisfactory method was found for accurately expressing the amount of erosion. The data for the Gaco Neoprene coating were obtained from a private communication. Except for the one case indicated, the time values used

were those reported for first erosion through the first ply of fabric. Straight lines were drawn for these data, but a different slope was obtained than for the pulsating-jet tester, indicating the following approximate relation:

$$t = \frac{K}{v^i}$$

The velocity exponent for the Gaco Neoprene coating was approximately nine, but since the straight line was drawn from only two datum points for this material only, this value is not considered of great significance.

The great difference in the rate of change of failure time with velocity for the pulsating-jet and whirling arm testers may be accounted for by the difference in particle mass (jet *versus* drops) and rate of particle impingement. The larger impinging mass and faster rate of impingement of the pulsating jet evidently results in much more severe erosion than is obtained with the whirling arm tester. If this difference in erosion severity results in only an acceleration of failure time at the speeds involved, the difference is not serious. Certain evidence, however, indicates that a difference in the mechanism of erosion may exist.

With the pulsating-jet testers, most of the materials which showed good resistance to erosion were relatively hard, while softer tougher materials, commonly considered to have good abrasion resistance, were readily eroded. The Gaco Neoprene coating was no exception to this rule. While many soft coatings containing elastomers have also failed readily on whirling arm testers, the Gaco coating has shown good erosion resistance as indicated in Fig. 8. Since the coatings were applied by different investigators, a difference in materials or application technique may account for the difference in test results. If this is not the case, however, it appears that the coating is capable of absorbing the energy from the impingement of single drops, spaced at intervals to allow time for recovery, but fails when subjected to the rapid impingement of larger volumes of water. Presumably at some higher velocity the energy of impingement of single drops would cause rapid failure of the Neoprene coating, but this velocity may be extremely high.

The data from different testers for harder materials are in general quite comparable, but since the whirling arm tester appears to closely duplicate service conditions, data from jet-type testers on softer types of materials should be questioned. As noted previously, it is expected that adjustments can be made on the interrupted-jet type of tester which will result in impingement masses similar to raindrops. These drops can, if necessary, be spaced at intervals and may duplicate service conditions accurately.

Conclusions

Consideration of all of the information on rain erosion available to the author at the time of preparation of this paper indicates general agreement on the following:

1. The time required for serious rain erosion of most materials is inversely proportional to some large power of the relative velocity of the water with respect to the surface of the material being eroded.

2. Both conventional aircraft finishes and conventional low-pressure glass cloth - polyester resin laminates used in aircraft have poor resistance to rain erosion and are unsatisfactory from this standpoint.

3. Certain special laminates, particularly those with smoother more homogenous surfaces and more void-free construction, have better rain erosion resistance than conventional laminates.

4. Certain protective finishes have better rain erosion resistance than conventional finishes, and finishes can probably be devised to protect at least partially the exterior surfaces of airplanes from rain erosion at present common flight speeds.

Future Work:

Additional development work on test equipment for evaluation of rain erosion resistance appears to be desirable to attempt to achieve the following goals:

1. Correlation of tester results with standardized flight conditions.

2. Establishment of a quantitative rating system for evaluating rain erosion resistance.

3. Design of test equipment as simple in operation and specimen requirements and as free of hazard to personnel as is consistent with achieving the goals above.

Additional investigations of plastic laminate configurations and erosion-resistant finishes are indicated in order to find satisfactory solutions to the rain erosion problem, particularly at the higher speeds probable for future airplanes.

References

(1) R. McG. Robertson, R. J. Lobisser, and R. E. Stein, "High Speed Rain Abrasion of Glass Cloth Laminates," *Industrial and Engineering Chemistry*, Vol. 38, pp. 590–591 (1946).

(2) Paul Hawley, "Glossy Black Camouflage," *Process Engineering Report No. LN 2107*, Northrop Aircraft, Inc., February 19, 1945.

(3) Edmund E. Callaghan, "An Investigation of Rain-Erosion-Resistant Coatings for Use on Radomes," *Memorandum Report E 5125*, Nat. Advisory Committee for Aeronautics, September 25, 1945 (withdrawn from circulation).

(4) W. J. Humphreys, "Physics of the Air," McGraw-Hill Book Co., Inc., New York, N. Y., p. 280 (1940).

(5) F. A. Berry, Jr., E. Bollay, and N. R. Beers, "Handbook of Meteorology," McGraw-Hill Book Co., Inc., New York, N. Y. pp. 252–263, (1945).

(6) A. R. Jones and Wm. Lewis, "Recommended Values for Meteorological Factors to be Considered in the Design of Aircraft Icing Prevention Equipment," *Technical Note 1855*, Nat. Advisory Committee for Aeronautics, March, 1949.

(7) A. G. Guibert, E. Janssen, and W. M. Robbins, "Determination of Rate, Area, and Distribution of Impingement of Waterdrops on Various Airfoils from Trajectories Obtained on the Differential Analyzer," *Research Memorandum No. 9A 05*, Nat. Advisory Committee for Aeronautics, February 16, 1949.

(8) R. L. Stoker, "Erosion Due to Dust Particles in a Gas Stream," *Industrial and Engineering Chemistry*, Vol. 41, pp. 1196–1199 (1949).

(9) M. A. Fisher and E. F. Davis, "Studies on Fly-Ash Erosion," *Mechanical Engineering*, Vol. 71, pp. 481–487 (1949).

(10) J. H. Gibbud, "Water Abrasion Resistance of Glass Cloth Reinforced Plastics," *Memorandum Report*, Owens-Corning Fiberglas Corporation Research Laboratories, May 26, 1947.

(11) F. B. Cole, "Design and Construction of Jet Type Rain Impingement Tester," *Report No. 6853*, Lockheed Aircraft Corporation Engineering Laboratory, February 17, 1949.

(12) "Rain Erosion Properties of Plastic Materials," *Air Force Technical Report 5686*, United States Air Force, Air Materiel Command, Dayton, Ohio, May 11, 1948.

DISCUSSION

Mr. A. M. Malloy*[1] (*presented in written form*).—In general, the writer is in agreement with the authors on the subject of laboratory testing the rain erosion of plastic laminates and, to a limited extent, organic protective coatings, particularly in regard to the authors' conclusions and outline of future work contemplated. In view of the fact that this is a new field of engineering endeavor, the paper must be reviewed with the thought in mind that there are very few precedents to provide guidance. Workers are literally grop-

* The opinions expressed herein are those of the writer and are not necessarily official opinions of the Bureau of Aeronautics or the Department of the Navy.

[1] U. S. Navy, Bureau of Aeronautics, Washington, D. C.

ing at the present time, and, accordingly, many changes in testing procedures can be expected as the work of the various investigators of rain erosion finds its way into laboratories and eventually into print. The suggestions detailed below are offered to assist in orientation of the work in this field of endeavor rather than to establish rigid standards of accomplishment.

It is agreed that impingement of water and dust particles at high speeds is the cause of the observed erosion of laminates and organic coatings on metals. However, the erosion resistance of fiberglas laminates may be dependent to a major extent on the anchorage of the glass fiber to the laminating resin employed in manufacture of the material. Therefore, in the case of these laminates, this is considered to be primarily a material problem; the development of a coating for the laminate being a necessary corollary.

The authors' data on raindrop size are considered particularly appropriate in work of this nature and attention is rightly paid in the test work to the diameter of the drop and the precipitation intensity.

The Bureau of Aeronautics, in its work, has concentrated its efforts on whirling arm test devices such as the Cornell Aeronautical Laboratory 500-mph. apparatus developed for the Air Materiel Command, and the University of Louisville apparatus which operates at speeds of approximately 700 mph. As stated by Messrs. Grace and Frey, it is considered that tests on whirling arm test devices more nearly simulate service conditions than do jet testers. However, it should be noted in passing that the precautions to assure requisite safety in the operation of high-speed whirling arm test devices tend to limit the construction of such facilities to those organizations willing and able to institute adequate safety measures. For this reason, as well as the excessive noise generated during the operation of whirling arm test devices, their construction by small laboratories is not recommended. Conversely, uncertainty regarding the variables encountered with jet devices such as that of North American Aviation, Inc., may be an over-riding consideration in favor of the whirling arm type of apparatus, as was the decision in building the University of Louisville test equipment.

Tests of erosion using a blast of carborundum dust with or without accompanying water will measure only the resistance to erosion caused by the needle-like, impinging particles. Such tests neither simulate rain erosion at high speeds nor evaluate any other factor worthy of consideration in a well-planned erosion test program. The Bureau of Aeronautics has therefore discontinued all tests with carborundum impingers.

In rain erosion test work, it must be recognized that, in the absence of adequate accompanying adhesion, such tests may result in meaningless data, since the maximum obtainable erosion resistance is not realized if the area under examination is capable of lateral movement at the metal-film interface under the force of impact of the eroding particles. This tendency is believed to exist when impacting particles, such as rain, impinge on the forward portion of the aircraft wing, vertical fin, etc. If a coating possessing strong adhesion forces at the metal-film interface were available, it would resist this tendency. In view of the above, one should not attempt to test erosion resistance unless there is adequate accompanying adhesion to justify conducting such a test. For example, an envelope of loosely adhering rubber on a metal or glass cloth substrate logically should not be tested for erosion resistance because the only property which would be evaluated would be the resistance of the rubber to mere abrasion or wearing away, and the data would bear no relation to performance of the material as a finish under the impact of raindrops at high speed on these substrates.

The Bureau of Aeronautics is currently concentrating major efforts on the development of a highly extensible coating for the leading edges of high-speed aircraft in the firm belief that this type of materials is required to resist the cavitation and erosion effects of impacting particles in the sub-sonic and transsonic ranges, rather than a hard or porcelain-type coating, as has been advocated in some quarters. In this connection, although this has not as yet been confirmed, it is believed that the coating flows around the impacting particles, dissipates in a very short period of time the energy resulting from the impact, and the coating quickly rebounds to its original contour. Speed of recovery is therefore an important factor. It is entirely possible, however, that a limiting velocity will be encountered in the super-sonic range, beyond which the efficacy of extensible organic coatings will be nullified. It should be noted that extensible materials have displayed in preliminary tests a manyfold resistance to erosion on the whirling arm test device. In the formulation of high-speed coatings for aircraft leading edges, a combination of thermoplastic and thermosetting materials, for example, phenolic-elastomers, is suggested for experimentation. It should be recognized that ease of repair of the film in service is an important factor in the ultimate choice of a coating. In order, therefore, to assist individuals attempting to formulate high-speed aircraft coatings, an approximate desirable goal, which still remains very flexible, is set forth below for guidance:

Tensile strength	6000 psi., min.
Adhesion to clad aluminum alloy	6000 psi., min.
Elongation of film at rupture	Greater than 100 per cent, preferably over 500 per cent
Tensile product = $\left(\frac{\text{Tensile strength} \times \text{elong. at rupture in per cent}}{1000}\right)$	Greater than 600, preferably over 3000
Erosion resistance at 700 mph. in a rainfall of 1.0 in. per hr., average diameter of drops 1.0 mm	30 min., min.
Softening temperature	Above 250 F.
Thickness of coating	0.003 in., max.
Moisture resistance	Satisfactory
Hydrocarbon test fluid resistance	Satisfactory
Florida outdoor weather exposure	1 yr., min.
Curing cycle	Not over 300 F. for 20 min.
Smoothness	Shall require little or no buffing or rubbing
Color	Glossy sea blue, A-N color No. 623

It is hoped the foregoing will be accepted in the spirit in which it is offered, namely, as the basis for preliminary work in order to establish a goal for workers in this field.

The tensile strength and elongation at rupture should be conducted on free films, employing an hydraulically operated or electronically controlled gear-driven tester capable of operation at constant rates of loading, rather than the customary constant rate of travel. The adhesion should be determined with a device such as the Interchemical Adherometer, employing a blade of suitably selected material, or an electromagnetically operated adhesion tester such as that of Soller of the University of Cincinnati. Routine tests, standardized by comparison with the above, might quickly and profitably be conducted with A.S.T.M. Method of Test for Tensile Properties of Adhesives (D 897 – 49),[2] employing metal test plugs. In choosing an appropriate cement for performing the latter test, it should be noted that Vinylite XYHL has shown outstanding performance in preliminary work with aluminum test plugs, yielding adhesion forces in the neighborhood of 7000 psi.

For what the following observations may be worth, it is disclosed that lubricating oil-covered coatings whirled at 700 mph. on the University of Louisville

[2] 1949 Book of A.S.T.M. Standards, Part 4, p. 789.

TABLE IV.—COMPARISON OF SOME LABORATORY RAIN EROSION TEST RESULTS WITH SERVICE DATA.[a]

	Service Item	Service History	Rotating Arm Tests			Jet Impingement Test, North American Aviation
			Air Materiel Command,[b] 265 mph.	Cornell Aeronautical Laboratories, 250 mph.[c]	Cornell Aeronautical Laboratories, 500 mph.[d]	
1. Conventional laminates.....	Nose radome (slight curvature)	Erosion through several plies after 10 hr. total flight time, partly through rain. Quantitative rainfall data unavailable	Erosion through first ply after 30 min.	Erosion through first ply after 8 min.	No data	First ply eroded in 1000 cycles at 450 mph. Severe damage in 1000 cycles at 500 or 100 cycles at 550 mph.
	Vertical stabilizer tip (sharpley curved) (Fig. 2 in report by Grace and Frey)	Severe erosion after 5 min. at 400 mph., heavy rain and hail				
2. Void-free laminates	Nose radome (slight curvature)	Very slight damage to first ply after 19 hr. heavy-to-moderate rain at 400 mph.	Slight damage to first ply after 2 to 3 hr.	Erosion through first ply after 25 min. A specimen with 4-in. radius of curvature was eroded through first ply after 190 min.	Erosion through 2 to 3 plies after 1½ min.	Insignificant damage caused by 100 cycles at 500 or 600 mph. Severe damage after 1000 cycles at 500 or 600 mph.
3. Neoprene coating over conventional laminate	Vertical stabilizer tip (sharply curved) (Fig. 2 in report by Grace and Frey)	No damage after 10 hr. heavy-to-moderate rain at 400 mph.	No damage after 13 hr.	Coating eroded after 5 to 6 hr. First ply eroded after 8 hr. Neoprene coating on void-free laminate eroded after 7 to 10 hr.	Neoprene coating on void-free laminate eroded after 10 min. Erosion through first ply after 20 min.	Coating failed in 10 cycles at 450 mph.
4. Pregelled coating	Nose ring (Fig. 1 in report by Grace and Frey)	Coating badly damaged after 5 min. light rain at about 350 mph. Reliable speed data unavailable	Coating failed after 2½ hr. First ply eroded after 4½ hr.	None tested	No data	No damage after 1000 cycles at 550 or 100 at 600 mph. Coating failed after 1000 cycles at 600 mph.
5. Interchemical 4A drum liner (phenolic) coated over laminate	No data	No data	Coating failed in 15 min. First ply eroded in 45 min.	Coating damaged in 45 to 60 min. Several plies eroded after 90 min.	Erosion through first ply after 2 min.	No damage after 1000 cycles at 550 or 100 at 600 mph. Coating failed after 1000 cycles at 600 mph.
6. Interchemical 4A drum liner (phenolic) over pregelled coating	No data	No data	No damage after 13 hr.	Coating eroded in 2 to 3 hr.	Coating eroded in 1½ min. Erosion through first ply in 2½ min.	No damage after 1000 cycles at 600 mph.

[a] Materials tested are all low-pressure glass fabric base plastic laminates. Some have coatings as indicated.
[b] 265 mph. through two water sprays from Sprayco 4B nozzles backed by 10 psi. water pressure. Flat samples.
[c] 250 mph., 1 in. per hr. rainfall, ¼-in. radius of curvature except as noted.
[d] Same conditions as footnote *c* except 500 mph.

test device were unaffected after 7 min. of rotation (it is not known how many more minutes the specimen would have continued unaffected, but unfortunately the test was discontinued). The specimen was removed and the oil was cleaned off with solvent. The specimen was then reinserted in the test device and failure resulted in less than one minute of rotation. Repetition of this treatment on the wings of an F2H airplane by the Bureau of Aeronautics with AN-G- grease has shown that the greasy film definitely protects the paint against the onset of erosion of dust particles at speeds in the neighborhood of 500 to 600 mph. for several hours. However, no rain was encountered in these flights, and these tests must, therefore, be considered highly preliminary.

Since the Bureau of Aeronautics' planned program of work with the University of Cincinnati adhesion tester will tax the capacity of this instrument to the limit for the next 18 months, tests on this instrument other than those already assigned regrettably cannot be undertaken.

In conclusion, it is gratifying to note a tendency toward general acceptance of the theory of an extensible finish for solution of the current leading edge paint problem on high-speed aircraft, a theory advocated and advanced by the writer for many years. Tests of such parameters of performance as erosion resistance, adhesion, film properties, etc., must be conducted on a quantitative basis if the development and evaluation work on new high-speed coatings is to result in acceptable materials in the foreseeable future. The work of the Bureau of Aeronautics is pointed in this direction, and some finishes under development; for example, Neoprene latexes applied over a rubber cement prime coat, using an appropriate intermediate or tie-coat, have shown sufficient promise to warrant a new note of optimism after the past several years of highly pessimistic outlook, particularly during a period when the speed of military aircraft had far outdistanced developments in organic coatings.

The authors of this paper are to be commended for a timely and excellent presentation. The results of correlation of this test method with Cornell's whirling arm test method, which is the present Navy standard, should prove highly interesting.

MR. JOHN K. LONG[3] (*presented in written form*).—To be of value, a laboratory test for rain erosion resistance should correlate with service test data, at least as far as rating materials in the same order is concerned. Some service test data are presented here for comparison with the laboratory tests. It has been pointed out in the paper that there are some cases where the jet test does not correlate with the rotating-arm test. Data are now available which indicate that the jet test also fails to correlate with service in some cases. Before considering the service data, a recent series of tests by the Cornell Aeronautical Laboratory providing quantitative information on the effect of radius of curvature of leading edge sections tested on the Cornell rotating-arm tester should be mentioned. It was shown, for instance, that erosion was initiated on a ¼-in. radius specimen in about one tenth the time required for a 4-in. radius specimen. This correlates with the fact that in service the sharply curved leading edges of vertical stabilizers have eroded more frequently and rapidly than more generously curved nose radomes. It has also been observed that a series of materials will be rated in the same order on the rotating-arm test whether they are tested all with small radii of curvature or all with large radii. With these effects of the radius of curvature kept in mind, it is possible to interpret the miscellaneous service data that have been received to date, and to com-

[3] Air Materiel Command, Dayton, Ohio.

pare these data with laboratory test results.

It should be noted that the service tests run so far are limited, but they are still considered to be quite significant. A comparison of test results is presented in the accompanying Table IV, which is compiled from data from North American Aviation progress reports, Cornell Aeronautical Laboratory reports, and unpublished Air Materiel Command data.

Several interesting facts are evident from the table. First, service tests showed that a void-free laminate airplane nose section of slight curvature had better resistance to rain erosion than did a similar conventionally laminated part. Second, the Neoprene coating on a sharply curved vertical stabilizer tip showed no evidence of erosion after 10-hr. flight through rain, while several uncoated stabilizer tips wore out in just a few minutes under similar flight conditions. Third, a pregelled resin coating on a laminated plastic nose ring having a radius of curvature between that of the nose section and the stabilizer tip, eroded after 5-min. flight through rain at a speed of about 350 mph.

The laboratory rotating-arm testers rated the materials in an order similar to that obtained by service tests. For instance, the void-free laminates when tested with sharp radii of curvature showed some improvement over conventional laminates. In the case of flat samples which are more suitable to the techniques of obtaining better void-freeness, considerable improvement in rain erosion resistance was observed, just as is the case in service for relatively flat samples.

All laboratory rain erosion tests predicted that the pregelled coating when undamaged by crazing and cracking would give rain erosion resistance superior to the conventional laminate. In service, however, these coatings tend to crack, due probably to temperature cycling, which decreases their rain erosion resistance properties.

In agreement with service data, the Neoprene coating offered considerable protection to samples tested on the rotating arm testers. In the jet impingement test, however, this elastomeric type of coating failed quite rapidly, indicating that the jet test is not suitable for the elastomeric type of coating.

Another point of disagreement between the rotating arm and jet test is evident in the case of Materials No. 5 and 6 of the table, a baked phenolic coating (samples Nos. 17 and 18 in report of Grace and Frey, Interchemical 4 A drum liner). On the jet tester this hard, thin coating applied to the laminate appears very satisfactory, but on the rotating-arm type testers it is only slightly better than a conventional laminate. Applied over a pregelled coating, the phenolic appears to offer protection at 250 mph., but even this improvement disappears at high speeds on the Cornell rotating-arm test. Service test data are not yet available on 4A drum liner coated plastic laminates.

It is possible that the jet test tends to underevaluate the elastomeric coatings (like Neoprene) and over-evaluate the harder coatings (like Interchemical 4A drum liner). Interruption of the jet to resemble more closely the impacts of actual rainfall may, as suggested in the paper of Grace and Frey, improve this condition. Another serious drawback to the jet test is its concentration of impact on a single point, which causes local imperfections to be unduly influential.

An organized program of service testing for rain erosion resistance, sponsored by the Air Materiel Command, is now under way. These service tests when complete should make possible a better evaluation of the laboratory tests.

Mr. L. M. Perdue[4] (*presented in written form*).—This paper is an excellent summary of the test information so far available on rain erosion. The data presented show how little is really known of the basic mechanism of rain erosion and of the properties which must be emphasized in impregnating and coating materials in order to obtain the best possible resistance to rain damage.

With regard to finishes, it is well to suggest that more attention be given to the effect of surface preparation of the materials finished, in order that results will reflect the performance capabilities of the finish rather than improper surface preparation. For example, small residual amounts of water-soluble cleaners might result in poor adhesion of a permeable or hygroscopic finish under soaking. Or, in the case of polyester laminates, failure to completely remove parting agents might lower adhesion considerably under any test conditions. From the paper it appears that no information is available to show whether any correlation exists between tensile strength, elongation, modulus of elasticity, energy absorption, rate of recovery after loading, moisture permeability, and fatigue characteristics of materials with their rain erosion resistance. Such resistance does not appear from the data presented to be directly related to hardness alone since materials of equivalent softness appear to be both good and bad.

Tests have shown no noticeable difference in erosion of polyester-glass cloth laminates with temperature variations from 4 to 30 C. however variations might be possible on materials which themselves are more susceptible to variation of physical properties with temperatures.

While preconditioning by soaking was accomplished in one of the tests reported in the paper, more information is needed on the effects of outside exposure, soaking, and high- and low-temperature cycling on rain erosion susceptibility.

It is believed that future work should include both determination of the mechanism of erosion and the qualities most essential to the rain erosion resistance of coating and impregnating materials.

Messrs. J. K. Grace and G. C. Frey (*authors' closure*).—Just prior to the publication of this paper several modifications were made in the design and operation of the interrupted-jet-type tester. These changes consisted primarily of moving the specimen during testing so as to erode it along the circumference of a $\frac{1}{2}$-in. diameter circle and of eliminating the soluble oil from the eroding water. This oil had been added to the water to reduce wear of the pump piston. In tests with this modified interrupted-jet-type tester of the five materials most extensively tested with the Cornell rotating-arm-type tester, the results obtained by the two types of testers were found to agree satisfactorily as shown by the following conclusions quoted from a recent North American Aviation Engineering Research Laboratory Report (NA-49-340-3, dated June 3, 1950).

"By properly adjusting the operating conditions, the N.A.A. rain-erosion tester can be made to give substantially the same relative rain-erosion-resistance values as the Cornell tester. The following table shows the N.A.A. and Cornell test results for various materials with the N.A.A. tester adjusted to optimum operating conditions for a water slug impact velocity of 450 mph.:

RATIO OF FAILURE TIME OF SEVERAL TEST MATERIALS TO THE FAILURE TIME OF POLYESTER (SELECTRON 5003)—FIBERGLAS LAMINATE AT AN IMPINGEMENT VELOCITY OF 450 MPH.

	0.018-in. Thick Gaco Neoprene Compound	Plexiglas	Formica, Type CJP-11	Interchemical Corp., Type 4A, Drum Lining
Values calculated from data obtained with interrupted-jet-type rain erosion tester using a water slug of 1.08 mm. average diameter	95	2.5	10	2.9
Values calculated from data obtained with the Cornell rotating-arm-type rain erosion tester using a 1.0 in. per hr. rainfall rate	86	2.0	6.8	4.7

[4] Process Engineer, Boeing Airplane Co., Seattle, Wash.

Some Properties of Reinforced Grouted Brick Masonry[1]

By Norman W. Kelch[2]

Synopsis

The bases are given for the design of structural elements constructed of reinforced grouted brick masonry in Southern California. The basic requirements of building codes applicable in Southern California, including allowable working stresses, are excerpted and briefed. A description of construction procedure is given and rather recently developed data on tests of mortar, grout, and brick assemblies are presented including excerpts from a report on a rather extensive series of tests made at California Institute of Technology. Data are presented on results of tests on specimens of mortar, grout, and cores taken in the field, and, finally, comments are made on the present methods of taking field specimens in a desire to see such methods improved to produce test values which will more nearly represent the ultimate applications of the materials used.

THE purpose of this paper is to present an outline of present practice in the design and construction of reinforced grouted brick masonry in Southern California and also to encourage further research to develop additional design data for the use of structural engineers and for building code regulations, and thus to broaden geographically the use of this type of construction.

Reinforced brick masonry has been considered a potential type of construction since its use by Brunel in the building of the Thames River Tunnel in 1825. Since the advent of portland cement mortars, this type of masonry has been used successfully in various types of structures to resist vertical and lateral forces which induced compressive, tensile, and shearing stresses in the masonry.

While lateral forces include those due to dry and fluid pressure, wind, and earthquake which are by no means limited to any geographical area, nevertheless, it is in consideration of those due to earthquake which have been largely responsible for the development of reinforced brick masonry into an accepted and widely used type of structural element in Southern California.

Perhaps the most significant advance in its history has been the use of free-flowing grout, composed of portland cement and sand with or without admixtures, which insures the solid filling of all interior joints and the complete embedment of reinforcing steel. No brick headers or bonding courses are used, since the wythes of brickwork are bonded throughout by the cement grout. This method has been developed increasingly during the past 20 years, and is identified as Reinforced Grouted Brick Masonry, which will be referred to herein as R.G.B.M.

Working Stresses and Design

As a basis for design, it was recognized that the resulting effects of the combination of the materials used in R.G.B.M. closely parallel those of reinforced concrete, the chief physical difference being in the coarse aggregate—brick instead of gravel or crushed rock. The materials used in R.G.B.M. are all covered in A.S.T.M. specifications. Following are basic regulations condensed from the Uniform Building Code[3] 1949 Edition, herein identified as U.B.C.:

U.B.C. Provisions: Brick, cement, sand, lime, and steel are required to be of A.S.T.M. grades. Two types of mortar are permitted which shall meet compressive strength or proportion requirements by volume as follows: *type A*, 2500 psi., or one part cement not more than one-fourth part lime, and not more than three parts sand; *type B*, 1800 psi., or one part cement, not more than one-half part lime and not more than four and one-half parts sand. Grout of only type *A* mortar to which is added water to produce consistency for pouring without segregation is required in all reinforced brick masonry in which the prescribed allowable working stresses for R.G.B.M. are used.

The compressive strength of masonry, f'_m may be assumed or may be determined by tests. It may be assumed to be 60 per cent of the compressive strength of the brick used with type *A* mortar, or 45 per cent of the compressive strength of the brick used with type *B* mortar, but such assumed strength of masonry, f'_m, may not exceed 2000 psi. or 1500 psi., respectively.

The following is quoted from the Uniform Building Code:

> Tests made to determine the strength f'_m shall be made on not less than five prisms built of the material called for by the design, cured in moist atmosphere for 15 days, and then allowed to dry at least 30 days before testing. Tests shall be made in accordance with the procedure required for testing concrete cylinders. The prisms for beams and slabs shall be approximately 8 by 8 by 25 in., built in a horizontal position with unselected brick laid as stretchers in running bond, two bricks wide and three courses high, with ½-in. joints. Prisms representing walls shall be approximately 8 by 16 in. in plan and 16 in. high. Those representing columns and pedestals shall be approximately 8 by 8 in. in plan and 16 in. high. The compressive f'_m value shall be the average value of all prisms tested.

The U.B.C. allowable working stresses in reinforced brick masonry are shown in Table I. The examples, assuming the use of type *A* mortar and the required type *A* grout, are not in the code but are given by the author.

In Table I, the coefficients are identical with Table No. 24-F in the U.B.C. 1949 Edition. Examples have been added by the author to show how the stress coefficients are applied for assumed and for tested strengths of masonry, f'_m, using type *A* mortar.

All of the values shown in the examples except those in the column at the extreme right would be reduced one fourth when type *B* mortar is used.

A special inspector during construction is required on all R.G.B.M. when the design is based on a strength of masonry, f'_m, in excess of 1000 psi.

Los Angeles County and Los Angeles City Code Provisions closely follow the U.B.C. except that: (1) either type *A* or type *B* mortar may be used; (2) no provisions are made to establish masonry strength, f'_m, by test prisms; (3) the allowable working stresses are exhibited as pounds per square inch for each type of stress using the U.B.C. percentages applied only to masonry strengths, f'_m, of 1500 psi. and 900 psi. calling for 2500 psi. brick and 1500 psi. brick, respectively, and requiring continuous inspection on the job by a registered deputy building inspector. For uninspected work, the allowable stresses are shown reduced 50 per cent.

All Southern California building codes

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] This paper was presented at the Session on Concrete and Concrete Products held at the First Pacific Area National Meeting of the Society, San Francisco, Calif., October 10–14, 1949.

[2] Consulting Architect, Pasadena, Calif.; Technical Director, Brick Manufacturers Association of Southern California, Los Angeles, Calif.

[3] Promulgated by Pacific Coast Building Officials Conference.

TABLE I.—WORKING STRESSES IN REINFORCED BRICK MASONRY.

Type of Stress	For Any Strength of Brick Masonry, psi.	Examples (Using Type A Mortar. Type A Grout Always Required) — Assumed Strengths of Masonry f'_m Using Brick of Strengths Shown			Example if Tests of Masonry Prisms Show f'_m, Say, 2500 psi.[b]
		1666 psi. f'_m 1000	2500 psi. f'_m 1500[b]	3333 psi. or over f'_m 2000 max.[b]	
Compression, axial	$0.18\ f'_m$	180	270	360	450
Compression, flexural	$0.33\ f'_m$	333	500	666	833
Shear, no web reinforcement	$0.02\ f'_m$[a]	20	30	30	30
Shear, web reinforcement taking $^2/_3$ entire shear	$0.04\ f'_m$[a]	40	60	60	60
Bearing	$0.25\ f'_m$	250	375	500	625
Modulus of elasticity	$1000\ f'_m$	1 000 000	1 500 000	2 000 000	2 500 000
Modulus of rigidity	$400\ f'_m$	400 000	600 000	800 000	1 000 000
Bond (type A grout):					
Plain	80	80	80	80	80
Deformed	100	100	100	100	100

[a] 1500 f'_m, max.
[b] Special inspector during construction is required.
NOTE.—For combined stresses: wind and other loads, stresses may be increased $33^1/_3$ per cent.

and the U.B.C. require the design of R.G.B.M. to be based on the assumptions, limitations, and methods of stress determination specified for reinforced concrete.

In R.G.B.M. walls these codes further require minimum reinforcement of 0.002 times the cross-sectional area of the wall, not more than two thirds of which may be used in either direction. Most walls are designed to be reinforced vertically, with the required horizontal reinforcement being concentrated at the tops and bottoms of the walls. No other horizontal reinforcement is used or required except around openings. (Horizontal steel spaced about 2 ft. apart is usually required in public school buildings.)

In addition to the required minimum reinforcement, at least one ½-in. bar or equivalent is required on all sides of every opening which exceeds 24 in. in either dimension, extending 24 in. beyond the corners of the opening.

In any space containing reinforcement, the clear distance between the masonry and the reinforcement is required to be not less than ¼ in.

Construction of Reinforced Grouted Brick Masonry

The construction of R.G.B.M. is in fact more simple in many ways than header-bonded plain brick masonry. The over-all thickness of masonry may be varied as the design may require, since there are no bonding headers to set the thickness dimensions. The wythes need not be kept exactly level with each other except at openings and tops of walls.

All brick in the outer courses are laid with full head and full unfurrowed bed joints and all interior joints are filled with grout. Brick in the interior of thicker walls, piers, etc., are placed or floated into grout poured between the outer wythes. No bonding header bricks are permitted and bricks are not required to be laid in any type of overlapping bond since the cement mortars and grout thoroughly bond the bricks together whether laid in running bond or with all vertical joints in a continuous vertical line with bricks laid as stretchers, headers, roloks, shiners, soldiers, or sailors, as is commonly done in contemporary design.

TABLE II.—TESTS OF BRICKS.
(*Smith-Emery Co.*)

Sample Brick	Compressive Strength, psi.	Absorption, 5-hr. Boil, per cent	Absorption After 24-hr. Immersion (½ Brick), per cent	Saturation Coefficient, A.S.T.M. C 62-49, per cent
No. 1	7586	17.83	13.02	74.77
No. 2	7780	17.12	12.76	74.48
No. 3	4341	17.56	12.18	68.58
No. 4	4624	16.91	12.54	61.76
No. 5	3115	17.16	11.27	66.08
Av.	5489	17.31	12.35	63.13

In grouted brick masonry one outer wythe or tier of brickwork may be carried up three courses before grouting, but the other or others may be carried up not more than one course above the grout. Each pour of grout is stopped 1½ in. below the top of each course being grouted and properly puddled or stirred to insure solid filling of joints and complete embedment of steel. Head joints are required to be not less than ½ in. wide to insure grout filling of head or end joints which may not be filled with mortar.

By grouting each backup or inner course as laid, the excess of free water in the grout is absorbed into the brick and the grout condenses into a mass having a very low water-cement ratio at the time of initial set of the cement. In Southern California, the 24-hr. cold water absorption average for facing brick is about 10 per cent, and for building brick is about 15 per cent, with some production running about 12, with one running about 20 per cent. Virtually all brick are pre-wetted to bring the rate of suction at time of laying close to the 20 g. per min. or less as given in Explanatory Note following the A.S.T.M. Specifications for Building Brick: (C 62 – 49).[4]

Most foundations and footings are of concrete, the top surfaces of which are roughened or sometimes grooved to provide a mechanical bond or key for the masonry. Steel dowels are set in the concrete the same as for reinforced concrete structures.

Vertical bars are tied to the dowels at the bottoms and spaced out and tied to a temporary wood strip or bar along the tops and braced to maintain the bars vertically. At least ¼-in. clearance is maintained between steel and brick.

Horizontal bars are laid in the grout at the required locations. Column and pilaster rectangular hooping is laid in the mortar beds.

The upper ends of most walls are supported laterally by bond beams wherein the depth, *d*, is horizontal. Thus the bars are spaced apart horizontally as far as possible by using a so-called angle brick or using soaps (bricks halved lengthwise). The bond beams are designed to take the horizontal reactions of the walls both inward and outward (as required by code). Stirrups are used for additional shearing resistance in bond beams, as well as in other beams.

In constructing beams and lintels, a temporary wood soffit support is used. The positive, negative, and shear steel is used just the same as in reinforced concrete. Such beams have been built successfully to spans of 48 ft.

There are two elements in the construction of R.G.B.M. which appear noteworthy: the absence of so-called cold joints in brick masonry, and the fact that the grout being poured every few inches in height develops no apparent laitance to hinder good bonding.

Figures 1 to 6 illustrate some of the typical details of R.G.B.M. construction.

Test Data

Reinforced Grouted Brick Masonry

[4] 1949 Book of A.S.T.M. Standards, Part 3, p. 564.

Fig. 1.—Grouting Each Backup Course.
Note dam of mortar at end.

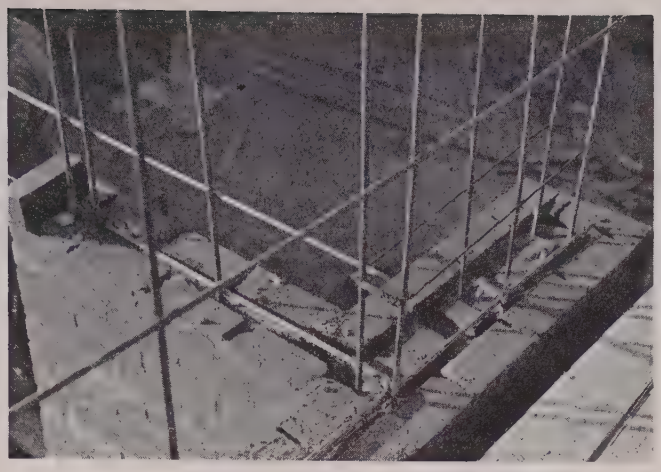

Fig. 2.—Intersection of 9- and 14-in. Walls.
Note that high walls with high stresses required horizontal steel.

has been developed into a technically sound and widely accepted type of construction due largely to the vast amount of past research and testing as indicated in bibliographic references contained in such publications as *Brick Engineering*,[5] B.M.S. Report No. 24,[6] etc., and also the work of such investigators as Raymond E. Davis,[7] Frederick J. Converse,[8] Raymond G. Osborne Bureau of Tests, Smith-Emery Co., and others.

In considering test data, it must be remembered that basically there are perhaps two types: those for use in making comparisons, and, in the words of Howard R. Staley,[9] those which truly represent values of materials in their ultimate application. Quoting the opening sentence of the synopsis of a paper by J. C. Pearson,[10] "Experience with vari-

Fig. 3.—Long Span Beam Under Construction.
Note grout left down 1½ in. for keying next courses. Some such beams span 50 ft.

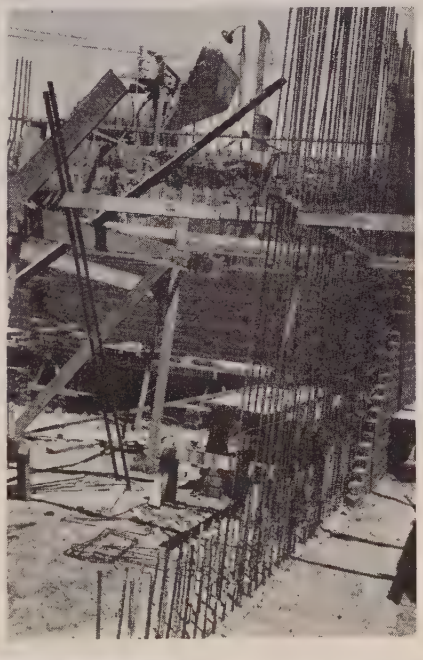

Fig. 4.—Dowel Steel in Footing; Two→ Layers of Wall Steel for 14-in. Basement Wall; Steel is Spaced and Nailed to 2 by 4-in. Wood, and Braced in Position.
Reinforcement is ½-in. round deformed bars at 6 in. o.c., two layers.

[5] Brick Engineering, Handbook of Design, by Harry C. Plummer and Leslie J. Reardon.
[6] Building Materials and Structures Report BMS24, National Bureau of Standards.
[7] Professor of Civil Engineering, University of California.
[8] Professor of Civil Engineering, California Institute of Technology.
[9] "Discussion on Compressive Strength of Cement-Lime Mortars," *Proceedings*, Am. Soc. Testing Mats., Vol. 44, p. 791 (1944).
[10] "Measurement of Bond Between Bricks and Mortar," *Proceedings*, Am. Soc. Testing Mats., Vol. 43, p. 857 (1943).

Fig. 5.—R.G.B.M. Wall Column.
Hooping laid in bed joints, not tied to col. steel.

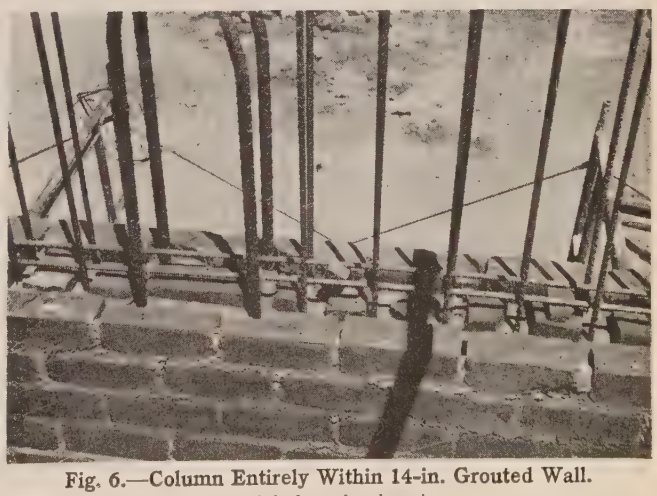

Fig. 6.—Column Entirely Within 14-in. Grouted Wall.
Grout left down for shear key.

TABLE III.—TESTS OF MORTAR.
(*Smith-Emery Co.*)

Cement.....1 sack (Blue Diamond type I)
Washed concrete sand.....3.0 cu. ft. (Blue Diamond)
Lime putty.....0.25 cu. ft. (Blue Diamond)
Mixed in mortar mixer

Specimen	Age, days	Compressive Strength, psi.	
		2- by 4-in. Cylinders	Mortar Prisms
No. 1.....	28	3455	3330
No. 2.....	28	3455	3300
No. 3.....	28	3400	3400
Avg.....	..	3437	3343
No. 1.....	72	4935	5085
No. 2.....	72	4820	4970
No. 3.....	72	4800	5060
Avg.....	..	4852	5029

TABLE IV.—TESTS OF GROUT.
(*Smith-Emery Co.*)

Cement.....1 sack (Blue Diamond type I)
Washed concrete sand.....3.0 cu. ft. (Blue Diamond)
Lime putty.....0.15 cu. ft. (Blue Diamond)

Specimen	Age, days	Compressive Strength of Grout Prisms, psi.
No. 1.....	28	2545
No. 2.....	28	2490
No. 3.....	28	2340
Avg.....	..	2458
No. 1.....	72	3505
No. 2.....	72	3610
No. 3.....	72	3590
Avg.....	..	3568

ous masonry bond tests has shown that most of them give discouragingly wild results, and that good reproducibility is attained, if at all, by artificial procedures which neither imitate the bricklayer's manipulation nor produce results anything like those obtained in practical masonry construction".

Although data obtained from tests on small assemblies (two-brick and three-brick) have been of value, nevertheless in establishing allowable working stresses in the building codes herein mentioned, the code engineering committees have given greater weight to data obtained from tests of much larger assemblies and of specimens cut from larger assemblies, which assemblies more truly represent the ultimate application of the materials used. Many of the latter data have been obtained from specimens and assemblies made at local brick plants on which detailed data on the technical properties of the materials used are not available.

Core Tests:

Eight-inch diameter cores are cut from masonry by a motor-driven coring machine bolted to the masonry. The coring is done with a concore core cutting machine designed and built by Frank L. Howard Engineering Co., of Los Angeles. Specifications require the contractor to repair the masonry carefully after cores are taken. Cores are capped, tested in compression, and the results are corrected using the strength correction factors as given in A.S.T.M. Methods (C42 – 49),[11] and reported as the compressive strength f'_m of the masonry.

For brevity, a detailed tabulation of the available data on the great amount of core testing which has been done in this area will be omitted. The records will show f'_m values for cores cut from actual jobs will generally average above 1600 psi. Unusual core tests have gone to a minimum of about 1000 psi., and to a maximum of about 3500 psi., the latter being with higher strength brick. Most of these cores were taken from masonry composed of the commonly specified 2500 psi., minimum brick laid with type *A* mortar and grout, and tested at 28 days.

As examples, four cores cut from Francis High School show an average of 2587 psi. with 2237 psi. minimum, and 2653 psi. maximum. From school buildings in Riverside (1949) two cores tested at the age of 102 days from an 8-in. wall show 3273 psi. and 3473 psi. using brick which had an average compressive strength of 6668 psi. with a minimum of 5850 psi. and a maximum of 7400 psi.; two cores, tested at the age of 44 days, from a 12-in. wall show 2294 psi. and 2412 psi. using brick which had an average compressive strength of 3353 psi., with a minimum of 2450 psi., and a maximum of 3748 psi. All were laid with type *A* mortar and grout.

Cores cut from a large assembly of grouted masonry at a local brick plant using brick laid with type *A* mortar and grout in an 8-in. wall gave values from 2602 psi. to 3346 psi. as shown in Table VIII.

Tests on cores, piers, units, mortar, and grout, using A.S.T.M. methods where applicable, were made and reported by Raymond G. Osborne, Bureau of Tests and Inspection, Los Angeles, in 1940 as shown in Tables V and VII. Type *A* mortar and grout were used in laying masonry 8 in. and 13 in. in thick-

[11] Standard Methods of Securing, Preparing, and Testing Specimens from Hardened Concrete for Compressive and Flexural Strengths (C42 – 49), 1949 Book of A.S.T.M. Standards, Part 3, p. 858.

TABLE V.—STRENGTH OF MORTAR AND GROUT—AGED 28 DAYS.
(*R. G. Osborne*)

	Mortar		Grout	
	Compressive Strength, psi.	Tensile Strength, psi.	Compressive Strength, psi.	Tensile Strength, psi.
8-in. wall.....	5129	495	5257	490
13-in. wall.....	4354	445	4700	438

Each value above is the average of three specimens tested.

TABLE VI.—COMPARISON OF COMPRESSIVE STRENGTH OF GROUT REMOVED FROM BRICKS, AFTER SHEAR OR TENSION TESTS, WITH STRENGTH OF GROUT CYLINDERS AT 28 DAYS.
(*F. J. Converse*)

Make of Brick	Grout			Number of Specimens	Grout from Brick Tests, psi.	Grout Cylinders, at 28 days, psi.	
	C	S	L			Vacuumed	Not Vacuumed
I.....	1	4½	0.50	4	1820	1900	1300
I.....	1	4½	0.25	2	2465	2250	1280
I.....	1	6	0	2	1776	750	700
I.....	1	6	0.50	2	1820	1000	700
B.....	1	3	0.25	3	3187	2100	2330
B.....	1	4½	0.15	2	2405	1900	1300
B.....	1	4½	0.50	6	1895	1900	1300
B.....	1	6	1.00	5	1614	995	700
C.....	1	3	0.25	2	1820	2100	2330
C.....	1	4½	0.15	2	2320	1900	1300
C.....	1	4½	0.50	4	2015	1900	1300
C.....	1	6	1.00	2	1480	995	700

NOTE.—The grout used for the brick tests did not contain the same amount of water as that used in the cylinders. In the brick tests the water ranged from about 500 ml. to 400 ml. per 1500 g. sand, whereas for cylinders the range was 350 ml. to 1275 ml. per 1500 g. sand.

TABLE VII.—STRENGTH OF BRICKS AND CORES USING MORTAR AND GROUT SHOWN IN TABLE V.
(*R. G. Osborne*)

Compressive Strength of Brick, psi.			Compressive Strength of Cores Aged 36 days, psi.	
Minimum	Maximum	Average	8-in. Wall	13-in. Wall
10 118	13 322	11 618	3 406	3 471
4 822	10 460	7 265	2 509	2 463
4 857	5 258	5 085	2 695	2 145
3 145	5 023	3 636	1 612	1 701

TABLE VIII.—STRENGTH OF CORES CUT FROM 8-IN. GROUTED WALL USING TYPE A MORTAR AND GROUT.
(*R. G. Osborne*)

Core	Age	Compressive Strength of Cores, psi.
No. 1.....	35 days	2602
No. 2.....	49 days	3076
No. 3.....	62 days	2800
No. 4.....	4 months	3346
No. 8.....	8 months	3221

TABLE IX.—SHEARING STRENGTH OF BRICK MASONRY.
(*R. G. Osborne*)

Double shear, psi.....	441	328	580	407	354	392	(417 avg.)
Single shear, psi.....	220.5	164	290	203.5	177	196	(208.5 avg.)
Type of failure:							
Per cent in unit.....	30	95	80	20	20	5	
Per cent in bond.....	70	5	20	80	80	95	

TABLE X.—RESULTS OF DIAGONAL SHEAR TESTS AVERAGE VALUES.
(*F. J. Converse*)

Brick	Time in Water	Mortar Mix			Shear Along Joint, psi.	Normal Pressure Joint, psi.
		C	S	L		
A.....	....	1	3	0.15	563	314
A.....	....	1	3	0.25	514	276
A.....	....	1	4½	0.15	584	328
A.....	....	1	4½	0.25	489	272
A.....	....	1	4½	0.50	526	291
A.....	....	1	6	0.50	542	305
.....	....	1	4½	0.50	440	255
.....	....	1	4½	0.50	382	218
.....	....	1	4½	0.50	638	351
.....	....	1	4½	0.50	581	325
.....	....	1	4½	0.50	454	265
.....	....	1	4½	0.50	641	365
.....	....	1	4½	0.50	591	343
.....	....	1	4½	0.50	499	282
.....	....	1	4½	0.50	422	236
Ah (1 value only).....	....	1	4½	0.50	527	271
.....	0 sec.	1	4½	0.50	539	315
.....	5 sec.	1	4½	0.50	496	282
.....	15 sec.	1	4½	0.50	525	303
.....	30 sec.	1	4½	0.50	686	389
.....	2 min.	1	4½	0.50	513	294
.....	5 min.	1	4½	0.50	607	344

TABLE XI.—TESTS OF BOND TO STEEL.
(*R. G. Osborne*)

Slip of Bar, in.	Bond Stress, psi., of Embedment					
	B-2	B-6	B-7	C-5	C-6	Average of 5
.0001.....	720	625	763	664	775	710
.0005.....	955	905	907	766	1170	942
.0010.....	1106	1036	1050	901	1250	1068
.0020.....	1230	1239	1205	1165	1274	1222
.0050.....	1367	1308	1311	1270	1348	1321
.0100.....	1425	1365	1374	1286	1420	1373
Ultimate.....	1750	1550	1842	1605	1775	1704
At approx. yield strength of steel	1460	1460	1370	1190	1250	..

ess with a 1½-in. thick grout joint. The cores cut from masonry made with brick having an average compressive strength of 3636 psi. gave values of 1612 psi. and 1701 psi., while those with brick strength of 11,618 psi. gave values of 3406 psi. and 3471 psi. Using similar materials, there were no appreciable differences in the strengths of cores cut from 8-in. and 13-in. walls.

Since allowable working stresses are determined from masonry strength and since such strength is generally being presumed to be the value of core strength, the core test has great significance.

Stresses in masonry are invariably vertical, horizontal or diagonal in a direction parallel to the face. Cores are tested in a position whereby the load is applied normal of the masonry. Believing that axial strength of grouted masonry may be greater than core strength and that perhaps a ratio may be established, pilot tests were made by cutting a core, a longitudinal prism, and a vertical prism from adjacent areas of a grouted wall, as shown in Fig. 10, then capping and testing them for compression in the direction of their long axes. The results were:

Core, 2285 psi.; longitudinal prism, 2915; vertical prism, 3155 psi.

A core cut from a beam built of similar materials at the same time as the wall showed 2050 psi.

A program of testing is now in progress to shed further light on this possible ratio of core strength to axial masonry strength.

Tension and Shear Tests

Many tests have been made and reported using the cross-brick couplet method for determining the strength of bond between bricks and mortar as a measure of the tensile strength of masonry, and using the three-brick punch-out method for determining the strength of bond between bricks and mortar as a measure of the shearing resistance of masonry. The paper by Mr. Pearson[10] and the discussions all seem to indicate that the results of tests on such specimens cannot be depended upon to represent the actual values in masonry structures. Building codes prescribe values for tension in flexure which is in fact modulus of rupture.

Osborne Tests, Shear:

In an attempt to obtain specimens of grouted masonry built and cured somewhat near job conditions, to be tested for their resistance to shear, a wallette was laid up, using soft mud brick and type *A* mortar and grout. The bricks in the first course on each side of an 8-in. wall were laid opposite, not staggered; the second course was laid in the same manner, but offsetting the one below by 1 in.; the third course was laid plumb over the first course. The mortar joints were ½ in. in thickness and the center or wall joint was 1 in. wide filled with grout representing a section of an 8-in. grouted wall. After set, but before hardening, the end joints were raked out. This provided a high center for the old three-brick push-out shear test method but with six bricks including a 1-in. grout joint. After curing in the open for 37 days, the shear was from 164 psi. to 290 psi. with an average of 208.5 psi. as shown in Table IX.

In the foregoing tests, the lack of load during curing and the type of testing are open to comment.

Smith-Emery Co. Tension Tests on Grouted Masonry:

Striving to obtain working stress values for shear in grouted masonry, four walls were constructed, 8 by 28 in. in plan by 58 in. in height; also one 8 by 64 in. in plan by 28 in. in height. The specimens were cured in open air and

TABLE XII.—TESTS OF BOND TO STEEL.
(*F. J. Converse*)

(*a*)	1:3:0.25 mix.....	953 psi.
(*b*)	1:4½:0.50 mix.....	788 psi.
(*c*)	1:6:1.0 mix.....	512 psi.

TABLE XIII.—TESTS OF BRICK COLUMNS USING BRICK MORTAR AND GROUT SHOWN IN TABLES II, III, AND IV.
(*Smith-Emery Co.*)

Assembly Number	Tensile Strength of Masonry, psi.	Moment Due to Load, in-lb.	Calculated Shear at Failure, psi.
W-1.....	864	217 500	32.4
W-1-A.....	756	197 000	100.1
WO-2.....	696	181 500	51.0
WG-3.....	716	186 600	69.5
OB-1.....	740	193 000	61.5

tested at ages of 70 to 84 days. They were tested as cantilevers and as beams as shown in Fig. 13 which we found produced failures due to tension in all specimens. The report, dated July 24, 1945, which refers to the assemblies as columns, follows:

All columns were laid up by the same mason, who tried to simulate field conditions as closely as possible. Results of the tests on bricks, mortar, and grout used are shown in Tables II, III, and IV.

The report of Smith-Emery Co. submitted drawings which show testing positions, dimensions, failure lines, etc.,

and total loads at failure. A summary of the data from the foregoing report is given in Table XIII. Methods of loading account for variations in shear values. The first four assemblies were built as walls, 8 by 24 in. in plan, 58 in. in height. The last was built as a beam, 8 by 60 in. in plan, 28 in. in height. The tensile strength values were from 696 psi. to 864 psi. The shearing values were from 32.4 psi. to 100.1 psi.

Raymond E. Davis Flexural and Shearing Tests:

In his report to members of A.S.T.M. Committee C-12 on Mortars for Unit Masonry, in 1933, Davis presented some selected results of an extensive series of tests to determine the flexural, adhesive, shearing, and bond strengths of brick and hollow tile masonry. These tests were carried out in the Engineering Materials Laboratory of the University of California, during the period from October, 1929, to December, 1930. The test program involved the testing of more than 1900 masonry and mortar specimens. Subsequently, another series of tests was made which involved the testing of 24 brick beams using a different type of lime.

From the results of these tests, two observations in particular are pertinent to this paper, namely: (1) Masonry pier assemblies, about 26 in. in height, which received increments of load beginning shortly after being laid by simulating superimposed masonry in building construction, showed values in flexure 40 per cent greater than similar piers not so loaded. The loads were removed before testing. (2) The values obtained with assemblies cured dry were substantially higher than those obtained from specimens cured wet, which would indicate that there was sufficient moisture in the mortar and brick to provide for the hydration of the cement. This was true in both series of tests. Obviously, a greater amount of moisture is present in grouted masonry.

Bond Strength of Reinforcement Steel in Grouted Masonry

Osborne Test:

The following data are from a report by Raymond G. Osborne Bureau of Tests dated August 27, 1938.

Construction of the Test Walls:

Two test walls, designated as "B" and "C" were each some 12 ft. 6 in. in length, 3 ft. in height, and 8 in. in thickness. They were constructed of two parallel brickwork sections enclosing a section of grout approximately 1 in. thick in which were embedded ⅜-in. deformed round steel reinforcement bars spaced 18 in. on centers vertically. . . . . We are informed that the walls were laid on May 11, 1938, and that the construction conformed to the specifications for brick, mortar, and grout embodied in the Los Angeles County (Uniform) Building Code, the grout having the proportions of 1:3 and the mortar of 1:3 with addition of 15 per cent of lime putty by volume to the cement. A free-flowing grout was used (having a slump of some 11.5 in.), poured into and completely filling the center joint at the completion of each course, and trowel stirred immediately after pouring. The vertical steel . . . was braced to reduce swaying during construction, though throughout the laying of wall "C" the bars were violently shaken when each course had been completed.

Technique of the Tests:

Having determined by the preliminary work on June 25 that an embedment in the neighborhood of 5 in. was more than adequate to completely develop the strength of the steel, the test specimens (chosen at random from the vertical steel bars projecting from the top of the walls) were exposed by means of holes cut through the walls, and cut off in such fashion as to leave sections of steel embedded between 3.0 in. and 3.68 in. in effective length. On the basis of the theoretical area of 1.18 sq. in. per lineal inch of ⅜-in. smooth round rod assumed, the areas in bond ranged between 3.54 and 4.34 sq. in.

The slip of the bars under stress was determined by means of a micrometer dial gage firmly clamped to the wall in such a fashion that its actuating arm rested against the lower face of that section of the rod under test.

The pull on the bars was increased in increments approximating 320 lb. each, and after each increase the pressure sustained until all evidenced movement at this pressure had ceased; this total slip was then recorded and an additional increment applied. At the completion of the tests the stress on the steel-grout bond per square inch of area embedded required to produce movements of 0.0001 (first observed movement), 0.0005, 0.0010, 0.0020, 0.0050, and 0.0100 in., and the ultimate pull-out was computed; and the results compiled (see Table XI).

Findings:

On the whole the evidenced bond values were exceptionally uniform and much higher than had been anticipated. The extreme stress to which the bond was subjected without appreciable movement ranged between 532 and 697 lb. per square inch of area in the five specimens tested, while that at which the first observed slip occurred ranged from 625 lb. to 775 lb. (all values computed on the basis of the theoretical area of 1.18 sq. in. per lineal inch of embedment of ⅜-in. smooth round rod).

It is interesting to observe that the ultimate pull-out of the specimens occurred in no instance until the pull on the rods had well exceeded the yield point of the steel (in the neighborhood of 50,000 psi.) and, hence, may be regarded as having occurred progressively. The required stress on the bond amounted to between 1550 and 1842 psi.

One of the primary purposes of the test program was to determine the effect of strong agitation on the reinforcement rods during construction (embodied in the construction of wall "C"). The results of the tests showed no appreciable divergence in trend, and as a result the data from both walls have been combined in the summary, though the behavior of the individual specimens may be identified as between the two walls by their designations of B and C in Table XI.

F. E. Richart's Bond Tests Between Steel and Mortar:[12]

Richart's bond tests were made by pulling the steel from embedment in masonry assemblies of four bricks forming a nominal cube.

Mr. Richart observed "that the deformed bars frequently produced splitting of the masonry pull-out block. If such bars were used in beams or walls in which some form of lateral ties were used, it seems very likely that a higher bond resistance could be developed."

It is interesting to observe that the values he obtained for ⅜-in. bars were close to those of the Osborne tests made some years previous. Also of interest is the paragraph of his Summary which states: "The studies of relation of joint width to bar size did not show conclusive results, though with ½-in. bars there was a slight increase in bond resistance as the joint width was increased from ½ to 1 in. This increase was from 10 to 20 per cent. In actual masonry, it would probably be impossible to use the minimum joint widths used in these small pull-out specimens, and a clearance of at least ¼ in. on each side of the bar seems desirable, especially in vertical joints, and using brick with high suction rates."

Building codes in Southern California require a minimum clearance of ¼ in. between brick and any reinforcing steel

F. J. Converse Tests: Project No. 1

Research Project No. 1 on R.G.B.M. was completed in 1941 at California Institute of Technology under the direction of Frederick J. Converse[13] for Los Angeles Brick Exchange, now Brick Manufacturers Association of Southern California. The report contains typewritten text and charts totaling 110 pages covering data on the following subjects: Mortar and Grout—Strength and Workability; Tension Bond—Mortar to Brick; Tension Bond—Grout to Brick; Shearing Strength of Mortar and Brick Joints; Shearing Strength of Grout and Brick Joints; Bond Between

[12] F. E. Richart, "Bond Tests Between Steel and Mortar Reinforced Brick Masonry," *Research Report No. 8.* Published by Structural Clay Products Institute, Washington, D. C.

[13] Professor of Civil Engineering, California Institute of Technology, Pasadena, Calif.

Reinforcing Steel and Grout—Direct Pull Tests; Bricks; Reinforced Grouted Brick Beams.

Following are excerpts from the body of this report:

Mortar and Grout—Strength and Workability

Sand.—In spite of the very similar grading curves, there was considerable difference in the way mortar made with the different sands reacted when used in the construction of masonry. This difference appears to be largely due to the sharpness or angularity of the sands. The sharp sands require more fines to make them workable than the smooth grained sands require. . . . In order to determine the effect of the character of the sand on the strength of mortar, a series of tests were made with two sands of markedly different angularity. . . . . There is no significant difference in the strength due to the character of the sand, within the limits of these tests.

Procedure for Making Specimens:

The method proposed by the A.S.T.M. Committee C-12 on Mortars for Unit Masonry, 1938 Report, was followed in mixing the mortar and making the specimens.

Test Results:

. . . . . In considering the effect of lime on the strength of mortar and grout, two opposing actions must be recognized. The retention of water tends to keep the water-cement ratio high, and therefore reduces the strength, while on the other hand the retained water is available for curing the specimen over a longer period of time, and thus increases the strength.

In order to determine the actual strength of the grout when it is poured into brick masonry, 36 prisms approximately 1 by 1 by 2½ in. were cut from specimens which had been broken in shear or tension bond. The results of compressive tests on these prisms are given in Table VI. Values obtained from the 28-day cylinder tests of grout before and after the application of vacuum suction are also shown in Table VI for the sake of comparison. The average value for five tests of the 1:3:0.25 mix is 2650 psi., with a range from 1270 to 4650 psi. For the 1:4½:0.50 mix, the average of fourteen tests is 1908 psi., with a range from 1417 to 2520 psi. For the 1:6:1 mix, the average of seven tests is 1575 psi., with a range from 1440 to 1880 psi.

Shearing Strength, Mortar and Brick Joints

Diagonal Shear Tests:

Tests for diagonal shearing strength were made on portions of a number of specimens previously tested in direct punching shear, but which failed on one side only. Two bricks with a mortar joint between them were placed in a compression testing machine with their diagonally opposite ends in a vertical line. Specially formed seats distributed the load over the bricks for a distance of about 2 in. each way from the corners, to prevent local crushing. Load was applied gradually until failure occurred. The unit shearing and normal stresses along the plane of the joint were calculated for the failure load, although in general the failure was by vertical splitting rather than pure shear. The calculated shearing stresses, however, were about three times as great as those obtained in the case of direct punching shear without normal load, indicating a probable angle of friction of at least 45 deg. The results are presented in Table X.

Bond Between Reinforcing Steel and Grout Direct Pull Tests

In order to determine the bond between reinforcing steel and grout, tests were made in which ⅜-in. round deformed steel bars were embedded in grout, stored for a definite curing period, and then pulled out of the grout by direct tension of the steel.

Preparation of Specimens:

Grout having 100 per cent flow without shock was prepared according to the method of mixing mortar suggested by A.S.T.M. Committee C-12 in the ASTM Bulletin for October, 1938, and previously described in this report. Brick and grout specimens were then made as follows:

Two bricks were submerged in water for 15 sec. and placed on a table with their 4-in. dimensions vertical and their 4 by 8-in. sides parallel and 1 in. apart. A ⅜-in. round deformed steel bar 18 in. long was placed vertically in the center of the space between the bricks, its lower end passing through a hole in the table and its upper end extending about 1½ in. above the top of the bricks. The spaces between the bricks at each end were sealed with a stiff mortar, and grout was poured between the bricks until the space was completely filled. No disturbance of the grout occurred after pouring, such as troweling or shaking the rod. The specimens were covered with wet burlap for 24 hr. and allowed to stand in the air of the laboratory until tested. Temperatures varied from 68 F. to 76 F. during curing, and at times the humidity was very low.

Six specimens were made of each grout mix, three for test at 30 days and three for test at 12 weeks.

The grout mixes were made with three ratios of cement to sand: 1:3, 1:4½, and 1:6, and for each sand ratio four mixes were made with different proportions of lime putty: 0, 0.15, 0.25, and 0.50 part lime putty. For the 1:6 cement-sand ratio an additional mix was made with 1.0 part lime putty. All proportions were by volume. About four months later additional specimens were made for check tests. . . .

Tests:

The specimens to be tested were placed in the testing machine in such a manner that the steel reinforcing bar passed through a ½-in. hole in a 4 by 4-in. plate. The bearing of the testing machine against the brick and grout was through this plate. . . .

In most cases the lugs on the reinforcing bars sheared out a hole in the grout as the steel was pulled out, but in sixteen cases in the 12-week tests, the brick or grout split shortly after the first rapid slip had occurred. In the check tests, final failure was by splitting the bricks in all cases. . . .

Discussion:

The only places where the laboratory tests may be more favorable than the field work are in the certainty of the proportions of the mix, the assurance that the grout flowed around the steel (that is, the steel was not against the brick and there were no considerable voids around the steel), and the knowledge that the bar was not disturbed after initial set of the grout. Points in the procedure tending to give low bond values are: (1) The grout was not spaded nor the bar vibrated after the grout was poured around the steel. (2) The bricks contained no moisture except that received during 15 sec. of immersion in water and 24 hr. under wet sacks. (3) The specimens were cured in the air of the laboratory during the summer months when the humidity was very low. (4) The direction of pull of the steel was in the direction of pour of the grout. It has been shown by Carl A. Menzel of Portland Cement Association (in *Journal*, Am. Concrete Inst., June, 1939, p. 517) that bond strength when the steel is pulled in the direction of pouring the grout may be as low as 50 per cent of the strength when the steel is pulled in a direction opposite to the pouring.

Conclusions:

1. Some lime is valuable in grout, the proportions varying with the mixes. For these tests the best mixes were: 1:3:0.25, 1:4½:0.50, and 1:6:1.0.
2. The average bond strengths at rapid movement (about 0.002-in. slip) for the best mixes were from 512 psi. to 953 psi. as shown in Table XII.
3. A study of the reasons for the variations in bond strength and ways of improving it, using one or two of the best mixes and a large number of samples, would be of value.

Bricks

The bricks for the tests were selected at the yards of the various manufacturers by a representative from the laboratory. . . . . Five bricks from each manufacturer were selected at random and tested for compressive strength, modulus of rupture, and absorption, using the standard A.S.T.M. procedure. . . . . The average compressive strength of bricks from different manufacturers varied from 3000 psi. to 6800 psi., and there was a similar large difference in the values of the modulus of rupture. The values of absorption varied from 11 per cent to 14.2 per cent for 24 hr. immersion. There is no correlation between strength and absorption. . . . . Immersion for 15 sec. was used as the standard method of moistening the bricks before making masonry specimens. The moisture in the bricks after 15 sec. immersion is from 20.8 per cent to 42.3 per cent of the moisture after 24 hr. immersion. . . .

Fig. 7.—Cutting Core from 14-in. Grouted Brick Wall.
Machine is lag bolted to wall.

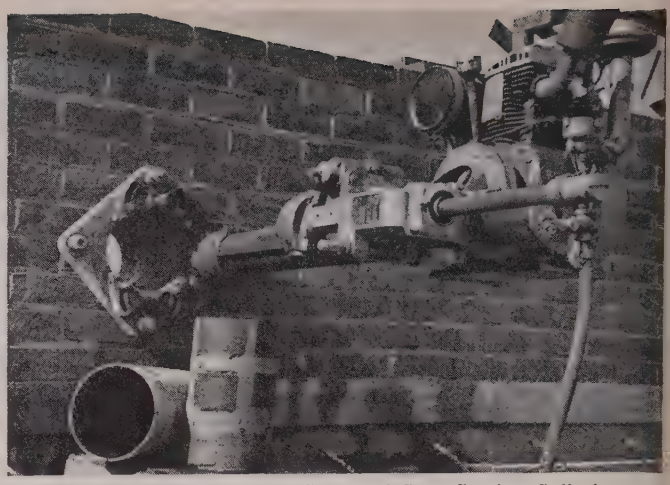

Fig. 8.—8 by 14-in. Brick Core and Core Cutting Cylinder.

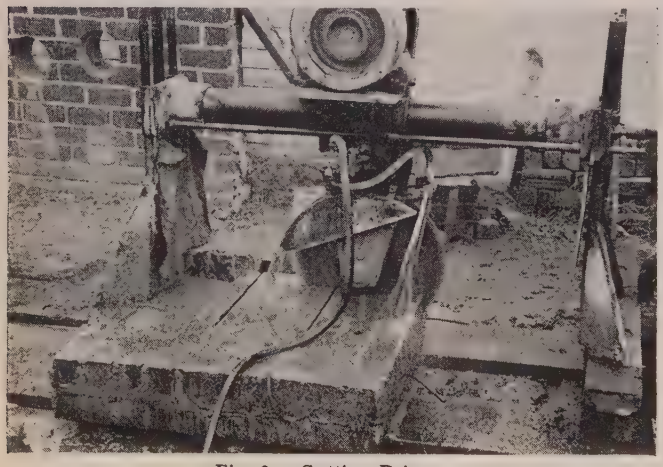

Fig. 9.—Cutting Prisms.

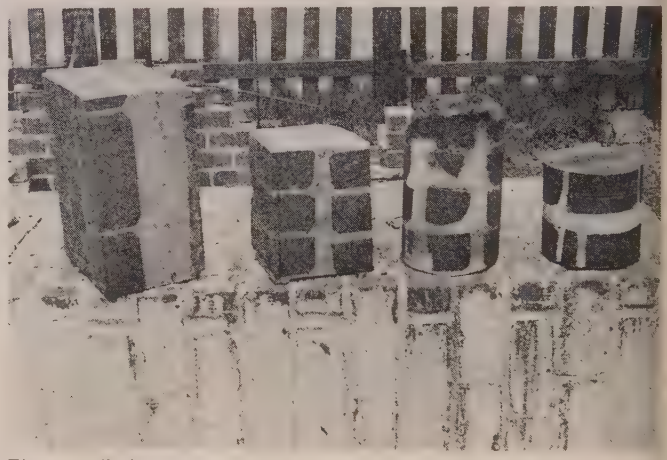

Fig. 10.—Left to right: Longitudinal Prism; Vertical Prism; Core Cut Vertically Through 12-in. Beam; Standard Core.

Fig. 11.—Method of Making Test Specimens of Grout.
Bricks forming molds are removed after set and before hardening of the grout.

Fig. 12.—Typical Conical Fractures of Grouted Masonry Prisms Tested in Compression.

The rate of absorption for all nine makes of brick was determined by the method proposed by L. A. Palmer ("The Construction of Weather Resistant Masonry Walls," Pamphlet of Structural Clay Products, Inc.). The bricks were immersed to a depth of $\frac{1}{8}$ in. on one face only, and the quantity of moisture absorbed was determined for each 1-min. interval up to 5 min. . . . The absorption during the first minute was much greater than that for any succeeding 1-min. interval.

Reinforced Grouted Brick Beams

In order to determine the true strength of the brickwork when used in reinforced beams, the following tests were made on beams designed with an excess of steel on the tension side, but with no stirrups. It was expected that the high compressive and shear stresses within the masonry would cause failure in some manner other than in the steel itself.

Specimens:

Four beams approximately 13 in. wide by 14 in. deep by 9 ft. long were constructed by a union mason at the California Institute of Technology. . . . . All beams had twelve $\frac{5}{8}$-in. round deformed bars on the tension side and no other reinforcing.

The beams were constructed by first building a wooden form 13 in. wide and 4

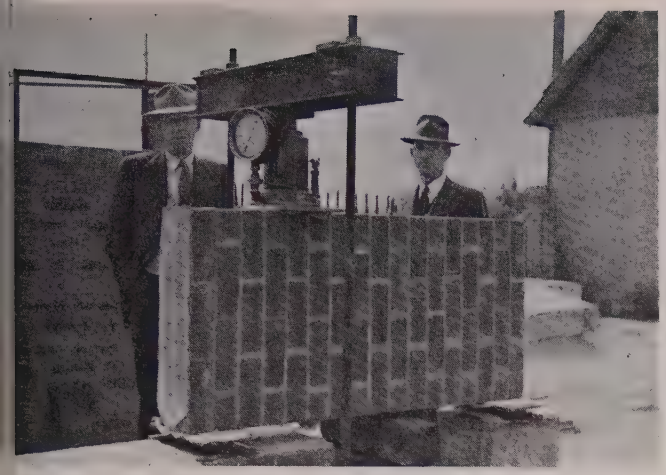

Fig. 13.—One of Several Positions of Specimens of 8-in. Grouted Walls.

Fig. 14.—Typical Fracture of 8-in. Grouted Wall Tested Laterally.

high, into which a bed of thick grout s poured to a depth of about 1½ in. e first layer of six bars was placed on the ut and worked into it. Another 1½ in. grout was poured over the bars, and the ond layer of six bars was placed. Grout s then poured to the top of the form. e top grout had more the consistency of rtar than of grout. The upper part of beam was constructed in three courses, ng mortar in the bed and end joints, l grouting the center joint after each rse was laid. . . . The beams were kept ist by sprinkling for two days, and were n covered with a wooden roof until ted.

sults:

All of the beams except No. 4 failed in izontal shear along the top of the grout ss enclosing the steel, at the point of tact with the first course of brick. No, ailed in horizontal shear through the ut along the top of the reinforcing steel. Table XIV shows the calculated shear- stress at failure and the corresponding mpressive stress in the top of the beam. ce the failure was in shear, the com- ssive stress does not represent the ul- mate for the beam. In these calcula- ns the grout on the tension side was as- ned to have cracked up to the bottom of e lower course of brick. It is apparent t both mortar and brick are important determining the resulting strength of e beam. The shearing stresses at fail- e for both of the beams made with brick were higher than those where brick E s used. Both beams using 1:3:0.25 rtar and grout were stronger than those h the same kind of brick but with 1: :0.5 mortar and grout.

Although the compressive stresses de- loped in the brickwork at maximum load not give the ultimate strength of the sonry, the values indicate that moder- ly high stresses were safely withstood, ecially in beam No. 2.

The maximum shear values shown by ese beam tests were from 250 to 600 r cent greater than the allowable rking stress in shear permitted by st building codes. Nevertheless, it is e author's opinion that greater values

Fig. 15.—Fracture of 8-in. Grouted Wall Specimen Tested as a Beam.

obtain in field construction work. The grout encasing the reinforcement in these beams was poured into wood forms. In field work the grout is entirely encased in brickwork which reduces its water-cement ratio and subsequently aids in its curing. The shrinkage of the grout in the case of these beams may explain the reason for the failures between the grout and the brick. The comparison of the values obtained with type *A* mortar and with type *B* mortar in the beam tests is noteworthy.

Figures 7 to 16 illustrate the types of testing and the types of failures as presented in the foregoing text.

Test Specimens from the Field

The California State Law[14] requires all public buildings constructed under the jurisdiction of the State Division of Architecture, which includes all public school buildings, be designed to resist a certain degree of lateral force.

Cores:

The specifications for R.G.B.M. walls of all public school buildings in California, and infrequently for other buildings, require compressive tests to be made on 8-in. diameter cores cut from the walls after the cores have cured for 28 days. See Figs. 7 and 8. They are tested and corrected as previously described.

Mortar and Grout:

The present state law[14] (now undergoing revision) contains the following:

403. (*e*) Mortar and grout specimens, continuously stored in moist air and tested at the age of 28 days, shall meet the following requirements:

1. *Tensile Strength.* The tensile strength for briquets one (1) in. square in

Fig. 16.—Detail of Fracture Shown in Fig. 15.

[14] State of California, California Administrative Code, Title 21, Public Works.

TABLE XIV.—TESTS OF R.G.B.M. BEAMS.
(*F. J. Converse*)

	Beam No. 1	Beam No. 2	Beam No. 3	Beam No. 4
	Wire Cut A Mortar	Soft Mud A Mortar	Wire Cut B Mortar	Soft Mud B Mortar
Max. shear, psi	128	174	80	122
Compressive stress at maximum load, psi	1 642	2 560	1 228	1 780
Modulus of elasticity, psi	1 268 000	1 365 000	1 800 000	1 300 000
Mix (cement:sand:lime)	1:3:0.25	1:3:0.25	1:4½:0.50	1:4½:0.50
Brick	E	B	E	B
Kind of brick	W.C.	S.M.	W.C.	S.M.
Modulus of rupture of brick, psi	907	1 150	907	1 150
Compressive strength, psi	5 540	6 210	5 540	6 210
Absorption, 24 hr., per cent	10.6	13.4	10.6	13.4
Moisture content, as laid, per cent	8.34	10.3	7.17	3.89
Total absorption, per cent	79	77	67.7	29

section shall be not less than one hundred fifty (150) psi. for lime-cement mortar, and not less than three hundred (300) psi. for cement mortar.

2. *Compressive Strength.* The compressive strength for cylinders two (2) in. in diameter by four (4) in. high shall be not less than nine hundred (900) psi. for lime-cement mortar, not less than one thousand five hundred (1500) psi. for cement mortar. The compressive strength of test prisms of grout made in brick molds not less than three and one half by three and one half by six and one half (3½ by 3½ by 6½) in. in size shall be not less than fifteen hundred (1500) psi. The brick shall be broken away from the prism after the grout has taken set but before it has hardened.

The use of thin blotting paper facilitates the removal of the bricks from the grout prisms. Grout joints average about 1½ in. in thickness between two brick wythes, thus between four bricks as a prism mold the amount of suction area is presumed to be about the same as in practice. The test results on grout prisms made in the field are invariably good, averaging at least 2500 psi. at 28 days.

The test results on mortar specimens made in the field generally fail to meet the requirements, although the core tests pass. This is leading to the study of a method of making such field test specimens which, again in the words of Howard R. Staley,[9] "More truly represent the values of mortars in their ultimate application."

It is readily recognized that the strength of mortar joints in masonry is affected by the suction of the brick which reduces the water-cement ratio; also by the moisture available in the brick for the hydration of the cement; and also, excepting vertical joints and the top courses of masonry, by some pressure exerted by the masonry above. The strength of the horizontal joints is of first importance in masonry subjected to forces inducing tensile and shearing stresses.

The work of Mr. Staley in comparing assemblage strength with mortar (cube) strength may well form the basis for making field specimens for testing the compressive strength of mortar. In his discussion the exact procedure used in making the "two-bat" specimens is not disclosed. We are experimenting with such a procedure applying a light load of three bricks laid dry immediately after assembly and remaining during curing. In order to be evaluated for code or specification requirements, probably a ratio, "Assemblage Strength to Mortar Strength" as given by Mr. Staley may be established. It is logical to assume that the results of tests on such jobs assemblage specimens made under job conditions would, in fact, closely represent the values to be expected in the masonry structure.

In making field specimens for tension tests of mortar, we are experimenting with the procedure of spreading mortar ½ in. thick on several damp bricks as used in the job, then allowing the mortar to remain on them for periods of minutes, then removing the mortar and pressing it into the briquet molds using thumb pressure. We are also trying this procedure for making the 2 by 4-in. cylinder specimens for the compression test.

The results of our tests on the field-made specimens described above are not yet available.

It is sincerely hoped that some rather simple standard method of making field specimens of mortar will be formulated in the near future wherein the test results can be depended upon to represent the values existing in the masonry.

Summary and Comments

1. The design and construction of reinforced grouted brick masonry are well established in Southern California from both technical and actual use standpoints.

2. In composition, reinforced grout beam masonry and reinforced concrete differ principally in their coarse aggregates; brick instead of gravel or crushed rock.

3. Grouting of brick masonry insures complete embedment of reinforcements and solid filling of all interior joints or spaces where vertical joints are not less than ½ in. in thickness.

4. Test data indicate that the strength of bond between steel and grout is at least as high as that obtained with concrete of equal mass strength.

5. While data obtained from tests of cores and masonry assembly prisms indicate a higher resistance to shear than is reflected in building codes, it is recognized that further research and testing of full-sized R.G.B.M. members is needed to reflect the values of shear, shear as a measure of diagonal tension, and tension-in-flexure which exist in actual structures. Present data appear to indicate that allowable working stresses are overconservative.

6. Being subject to practically immeasurable changes in volume after hardening, the codes permit two thirds of the required reinforcement in R.G.B.M. to be used in one direction with the other one third in the other direction concentrated at the ends or tops and bottoms of walls and panels, and this simplifies construction and inspection.

7. Using the same mortar and grout, the compressive strength of cores varies with the compressive strength of the bricks used, although the ratio does not appear constant, especially for high-strength brick. Data are needed to endeavor to set a ratio between the axial strength of grouted masonry and core strength.

8. Great stress should be placed on the need for data developed from tests made on grouted masonry specimens which closely represent actual construction factors of laying, grouting, loading, and long-time curing so that allowable working stresses may be more soundly determined.

9. The need is stressed for early development of standard methods for making mortar, grout, and small assembly specimens in the field to be used as check tests on jobs. The problem is complicated due to variations in water-cement ratios in mortars of various compositions which appear to have the same plasticities and workabilities under the trowel.

10. The age at time of testing specimens of masonry assemblies in which lime or other water-retaining admixtures are used appears to be of importance in evaluating strength of masonry f'_m. While 28 days is a more or less accepted age for testing concrete, it appears in many cases that greater age of masonry assembly specimens develops considerably greater strength. Perhaps a standard minimum of 60 days for such assemblies would be more indicative of actual strength.

11. In an attempt to solve at least in part some of the problems posed herein, the Brick Manufacturers Association of Southern California is now sponsoring an extensive program of research and tests involving about 60 re-

nforced grout beam masonry assembly pecimens as: beams with and without web reinforcement for shear; walls o be tested for values in diagonal tension and also tension in flexure; etc., using four types of bricks and four types of mortars. We are hoping that data obtained from this work will further advance the technical knowledge of reinforced grouted brick masonry.

DISCUSSION

Mr. Kelch (*author*).—Subsequent to he preparation of this paper the author cheduled tests on eight reinforced rout brick masonry beams approxiately 8 by 16 by 80 in. as pilot tests receding a larger program. These ests were conducted under the direcion of Frederick J. Converse, who tated in his report that all of the failres took place as a result of diagonal ension. As a measure of this diagonal ension the shearing stress has been calulated and tabulated.

In addition to perfecting a method of andling and testing the specimens, the urpose of the beam tests was to observe he effects of the three mortars used, and he difference in values obtained for good ork in which all bed and head joints ere full ½ in. thick and solidly filled nd grout joint puddled, and for poor ork in which bed joints were deeply urrowed and head joints were merely ipped with mortar and were varied from in. to ¾ in. in thickness with no special ttempt made to fill them with mortar or puddle the grout.

The specimens for the mortar tests ere taken during the construction of hese beams. The small difference beween the values for good work and oor work is noteworthy. The results re exhibited in the accompanying able XV. Figures 17 and 18 show the ypes of failures by diagonal tension. ust why the one specimen gave a value o much higher than the others is rather uzzling.

Using the same type materials, a few ouplets of two half-bricks were laid p with the cement-fireclay and with he plastic cement mortars, cured for 28 ays, and tested in compression.

The results shown in Table XVI xhibit an expected increase in strength ccording to the methods used in makng the specimens. Only the bottom alues would meet the code requirements for 2500 psi. (type *A*) mortar.

Since "standard sand" is recognized, he author poses the question: Why annot we find a "standard brick" probbly made by the dry press process which would have an ideal amount and ate of absorption, of compressive trength, and of surface texture? With uch bricks, we could conceivably delop standard methods of tests for the ompressive strength of mortar by usng the two-brick method, and also the ensile or bond strength of mortar by using say a five-brick high specimen tested for modulus of rupture.

Mr. Albyn Mackintosh.[1]—This paper points to the need for a freshness of approach to the problem of reinforced masonry. I believe that we lean too closely on reinforced concrete. I am particularly interested in the supplementary material supplied by Mr. Kelch. I notice some odd variations between plastic and standard cement mortars. It brings up the question of what does "plastic cement" mean? I also notice that poor work had an apparent higher strength than good work at the first crack. The results of the final group of tests should be very helpful in future designing.

Mr. George Solnar.[2]—Mr. Kelch, in this paper, has discussed a subject in which a good many engineers, architects, and the industry in this part of the West are interested but in many cases skeptical because they feel they do not have enough basic scientific information.

I think that he has done a good job of collecting the information that is technically applicable to our reinforced grouted brick masonry as it is known here on the Pacific Coast.

What is very obvious from this paper is that while brick masonry is an old form of construction, it has been neglected as far as a scientific approach is concerned. Mr. Kelch has indicated that reinforced grouted brick masonry may be a solution to the problem of designing masonry structures economically in an earthquake area, and then has proceeded to point out the need for developing new methods for control testing of this type of masonry construction.

One of the several factors that has deterred the scientific development of this type of construction is that the craft tradition is very strong in masonry construction. The need for scientific research is great. Interest on the part of the engineers and architects must be stimulated.

TABLE XV.—TESTS OF MORTAR AND REINFORCED GROUTED BRICK MASONRY BEAMS, AUGUST, 1949.

(*F. J. Converse*)

Tests on Mortar

	7 Days—Wet			28 Days—Wet			7 Days—Dried			28 Days—Dried		
	Std	FC	PL	Std	FC	PL	Std	FC	PL	Std	FC	PL
Tension Tests (Briquets), psi.												
Min.	261	180	105	315	218	181	285	210	130	340	295	205
Max.	325	187	160	346	245	192	360	237	190	364	317	233
Avg.	285	184	133	335	236	187	328	227	162	352	304	216
Compression Tests on Mortar (2 by 4-in. Cylinders), psi.												
Min.	1200	810	610	2230	1630	970	1570	1490	1150	2580	2020	1180
Max.	1370	1010	640	2380	1640	1010	1870	1500	1170	2880	2210	1300
Avg.	1285	910	625	2305	1635	990	1720	1495	1160	2730	2115	1240

Flexure Tests on Eight Reinforced Grouted Brick Masonry Beams (Using Above Mortars)

Loaded at center of span of 52 inches. Over-all length of beams, 80 inches. Beams were 2-bricks, plus 1½-in. grout joint in width, and 5 bricks in height, reinforced with six 5/8-in. deformed bars 2 in. above bottoms of beams.

Shear Stress at First Crack, psi.						Shear Stress at Failure, psi.					
Good Work			Poor Work			Good Work			Poor Work		
Std	FC	PL	Std	FC	PL	Std	FC	PL	Std	FC	PL
144	125	115	154	139	134	197	168	158	178	154	158
			...	120	125				...	245	130

Notes:

Standard Mortar Mix: 1 part cement, ¼ part lime putty, 3½ parts unwashed plaster sand.
"Std" means standard mix using portland cement.
"FC" means fire clay substituted for lime putty.
"PL" means mortar mix was 1 part plastic cement (a modified portland cement), 3½ parts sand.
"Wet" means mortar was placed in molds directly from the mortar board.
"Dried" means mortar was dried by being spread ½ in. thick on flat sides of damp bricks for five minutes before placed in molds.
Beams were cured in open air for 65 days.

TABLE XVI.—COMPRESSIVE STRENGTHS AT 28 DAYS OF MORTAR AND BRICK COUPLETS, PSI.

(*F. J. Converse*)

Brick strength was from 4548 psi. to 6240 psi with an average of 5340 psi.

		Cement-Fireclay Mortar and Grout	Plastic Cement Mortar and Grout
2 by 4-in. cylinders...	Wet	1635	990
2 by 4-in. cylinders...	Dried	2115	1240
2 half-brick couplets....	...	2860	2963

[1] Consulting Engineer, Mackintosh & Mackintosh, Los Angeles, Calif.
[2] Manager, Clay Brick Manufacturers of Northern California, San Francisco, Calif.

Fig. 17.—Types of Failures by Diagonal Tension.

Fig. 18.—Types of Failures by Diagonal Tension.

As Mr. Mackintosh previously mentioned, there is considerable need for a so-called fresh approach to the study of this type of construction. In part, I concur with this statement.

Mr. Harry C. Plummer.[3]—For several years the Structural Clay Products Institute has sponsored tests of reinforced masonry structures. The data obtained to date indicate that the bond, both between mortar and brick and between mortar and steel, is a very critical factor in determining the resistance of the structure to failure by diagonal tension. As a result, the Institute has conducted research to determine the important factors affecting bond. These appear to be the rate of absorption of the brick when laid, the surface texture of the brick, and the flow of the mortar.

In general, brick having absorption rates of approximately 20 g. (0.7 oz.) per min. give highest bond strengths when laid with mortar of mason's consistency. With a given brick, bond strength increases with mortar flow and with a given mortar, smooth surface brick, that is brick on which the "die skin" has not been broken, seem to give lower bond strengths than brick on which the die skin has been broken or removed. However, data on the effect of brick texture on bond are limited.

It has been the opinion of the Structural Clay Products Research Board (an advisory committee to the industry) that, until the principal factors affecting bond in reinforced masonry structures are understood and controlled, it would be difficult to specify construction techniques which might be expected to give reproducible results or could be applied to brick having a wide range of properties. For this reason we are still devoting a large part of our program to the study of bond.

Mr. N. W. Kelch (*author*).—I should like to ask those present what they would think of values obtainable in horizontal shear if the brick were cored. I think if the cores in the brick were small so that the mortar would key into them that they would materially increase the shear value of the masonry both horizontally and diagonally.

Mr. Plummer.—My guess would be that there would be very little difference between the solid brick and the cored brick. That is only a guess.

Chairman J. W. Whittemore.[4]—At Virginia Polytechnic Institute we took a particular make of brick, and keeping the saturation coefficient the same, the mortar flow, and so forth, we found no significant difference between those with core and those without.

Now, that was just on the *crossed* brick specimens in tension test. This, of course, may be altogether different on other brick specimens.

[3] Director, Engineering and Technology, Structural Clay Products Institute, Washington, D. C.

[4] Professor of Ceramic Engineering, Engineering Experiment Station, Virginia Polytechnic Institute, Blacksburg, Va.

Shortage of Engineers Forecast

The question of whether the country faces an oversupply or undersupply of engineers has been widely discussed. Much information and, unfortunately, some misinformation has been published.

In an article by Henry H Armsby, Associate Chief for Engineering Education, Office of Education, published in *Higher Education*, the facts and figures are carefully analyzed.

The article emphasizes the fact that engineering is a growing and expanding profession. Not only the total number of engineers, but also the ratio of engineers to total employment, has been steadily rising ever since employment statistics have been assembled.

The writer also points out "the continually increasing need for engineering and research in industry and Government; the tendency for engineers to develop new processes and services which create needs for new kinds of engineers and technicians; and the growing tendency of employers to recruit men with engineering training for jobs which have not in the past been considered engineering jobs, but for which an engineering background is becoming more and more useful. From 1954 to 1965 or later there will develop a serious shortage of engineers, unless the ratio of freshmen engineers to high school graduates is increased."

It is possible that the Korean situation will lend even greater significance to Mr. Armsby's analysis and conclusions.

Fire Protection Through Modern Building Codes

A second edition has now been published of "Fire Protection Through Modern Building Codes" prepared by B. L. Wood, Consulting Engineer for American Iron and Steel Institute. This is a very informative book on fire protection. Part 1 gives much factual data and discussion on the many factors that enter into fire hazards. Included are such important topics as classification of buildings by types of construction, height and area restrictions, and fire resistance ratings of materials and constructions based on the standard A.S.T.M. fire test method E 119.

The second part of this book contains the 1950 building classification and fire protection regulations. These suggested regulations reflect a careful study of provisions and regulations of many national organizations concerned with fire protection, as well as building codes of many cities.

This book has been published under the auspices of the American Iron and Steel Inst., 350 Fifth Ave., New York 1, N. Y., and further information concerning price, etc., can be obtained by writing to the Institute.

A Proposed Method of Test for Specific Heat of Thermal Insulating Materials[1]

By Norman H. Spear[2]

Synopsis

This paper describes an apparatus and a test method, under consideration for standardization, for the determination of specific heats of thermal insulating materials which incorporates a technique of extrapolation for instantaneous heat exchange in the "method of mixtures." Test data from three cooperating laboratories on similar measurements of the same material are presented and compared to the true value as determined by the National Bureau of Standards. A comparison of laboratory test results is given with summary of potential deviations due to individual techniques in an attempt to establish the best techniques adaptable for standardization.

Many recent technical papers have dealt with the measurement of specific heats and with application of new calorimetric techniques applied to these measurements. The methods of measurement described fall into three classes: (1) exchange of thermal energy with or without change of phase, (2) differential rates of heating or cooling due to thermal leakage, and (3) electrical or mechanical heat input methods. Many investigators have developed methods for specific heat determinations on particular materials which are satisfactory, but this leaves other investigators in doubt as to the applicability of a given test method to their specific problem. Thus it becomes necessary for each investigator to design his own test by using his judgment in selecting integral parts of other tests and combining these to make a test deemed by him to be the best solution for his particular problem.

The need for specific heat data for thermal insulation materials is important in unsteady state conditions because the thermal diffusivity (the thermal conductivity divided by the volumetric specific heat) is the controlling factor in heating or cooling time if the thermal conductivity and thickness of insulation are constant. This parameter actually defines the rate of temperature progression through a material under a variable temperature head. The importance of these data has been reviewed in a technical paper by Wilkes and Wood[3] in which they state that "...by consideration of heat capacity a more satisfactory reduction of insulation can often be made." Hill and Bell[4] have also considered this problem by describing a modification of Wilkes' and Wood's calorimeter in a recent paper. The need of a standard method for this measurement is self-evident, if some uniform standard for procurement of insulating materials is to consider this important factor, because no knowledge exists of the correlation between the existing different methods of measuring the specific heats of insulation materials or their reproducibility.

In conjunction with this problem, three independent cooperating laboratories[5] have conducted round-robin tests in order to explore a simple yet accurate method for measuring specific heats of thermal insulating materials. The basis of these tests has been an unpublished technical paper, "A Proposed Tentative Method for the Determination of the Specific Heat of Thermal Insulating Materials," prepared by E. B. Penrod, University of Kentucky, after a suggestion by Max Jakob. This suggestion included the technique of graphical extrapolation which is employed in this test for purposes of simplicity and accuracy in preference to calculation of the instantaneous value of heat exchange normally employed.

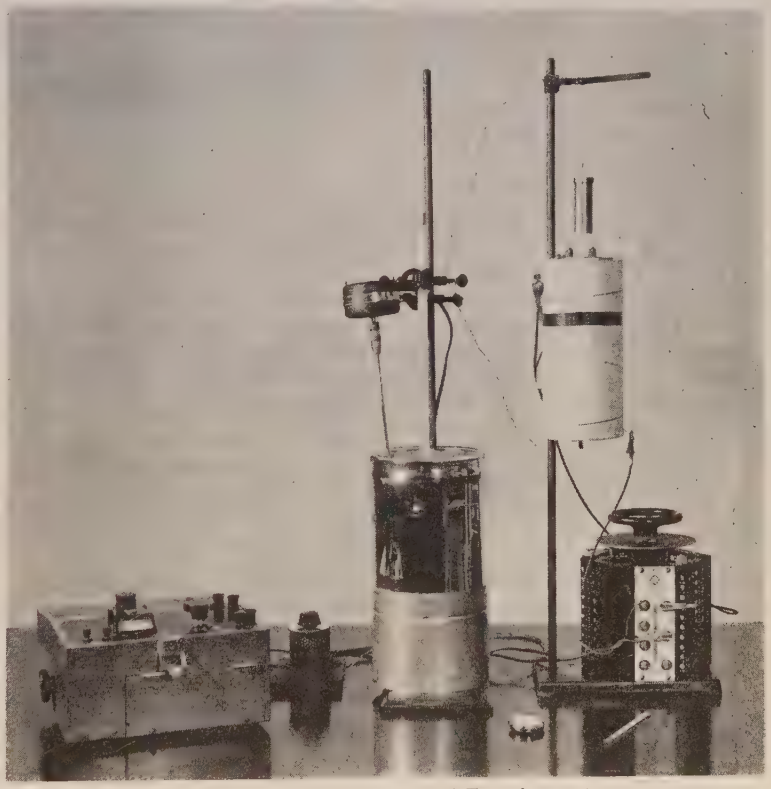

Fig. 1.—Photograph of Typical Test Apparatus.

Each cooperating laboratory has conducted tests on samples of the same material after calibration of their individual calorimetric interpretation of the initial specifications. A description of these tests and the results are presented

[1] This test method is under consideration by Subcommittee T-VII on Special Thermal Properties, of A.S.T.M. Committee C-16 on Thermal Insulating Materials. This paper is presented with the aim of eliciting comments and criticism and all communications should be addressed directly to the Subcommittee Chairman.

[2] Research Physicist, John B. Pierce Foundation, New Haven, Conn.

[3] G. B. Wilkes and C. O. Wood, "The Specific Heat of Thermal Insulating Materials," *Heating Piping and Air Conditioning*, Am. Soc. Heating Ventilating Engrs., June, 1942, pp. 370–374.

[4] H. Hill and R. M. Bell, "A Versatile Calorimeter for Specific Heat Determinations," ASTM Bulletin, No. 151, March, 1948, p. 88 (TP 96).

[5] The cooperating laboratories were: (No. 1) United States Testing Company, Inc., Hoboken, N. J.; (No. 2) Department of Mechanical Engineering, University of Kentucky, Lexington, Ky.; (No. 3) Department of Physiological Research, John B. Pierce Foundation, New Haven, Conn.

herein and analyzed in an attempt to find the simplest test apparatus with a retention of a degree of accuracy that will be acceptable for a standard test for procurement of thermal insulating materials.

Apparatus

The apparatus for this test was selected for simplicity, flexibility, low cost, and because the constituent parts are reasonably common in research laboratories. Figure 1 is a photograph of these parts in their respective test positions. The integral parts include a differential thermometer, a Dewar flask, stirrer, heating oven, and capsule. It is necessary to use a container for the test specimen to prevent the possibility of heats of reaction and of wetting between specimens and the liquid bath. Accessory equipment includes a thermocouple and potentiometer for measurement of the capsule and specimen temperature, a standard thermometer for calibration of the thermocouple and differential thermometer, a variac for regulation of the oven current, and a stop watch. If desired, a "catch" screen may be used in the Dewar flask to prevent breakage by the capsule and for central suspension of the capsule within the flask during test.

All of the parts shown in Fig. 1 may be purchased with the exception of the heating oven and the capsule. These were constructed from easily obtainable materials. The oven consists of approximately 70 equispaced turns of Nichrome V ribbon, $\frac{1}{16}$ in. by No. 26 gage, wound about a 10-in. length of 2-in. copper pipe which is insulated from the heater element by asbestos paper. The unit is then lagged with a standard 85 per cent magnesia pipe covering. The oven has a separable sliding top with slit notches at the interface of the halves for admission of the thermocouple wires and the suspension wires of the capsule. The bottom is closed during heating by a friction fitted cover. The entire oven assembly is mounted so that it may be swung over the calorimeter quickly.

The capsules used were hollow brass cylinders approximately 1 in. in diameter by 3 in. long, closed at one end. A cap, with or without a gasket, is threaded or soldered to the other end to produce a watertight fit. The cap incorporates a thermocouple well which protrudes into the capsule and permits measurement of temperatures of the materials within the capsule. The entire capsule is suspended centrally in the oven by a harness and very fine suspension wire. During tests this wire is cut and the capsule and harness permitted to fall into the bath in the Dewar flask, the thermocouple remaining in the oven.

Calibration and Test Procedure

The mechanism of this test is an exchange of thermal energy without change of phase, more commonly referred to as the "method of mixtures." The calibration and test procedure are identical with the exception that calibration consists of dropping the capsule, first empty and then filled with a specific heat standard, into the bath in the Dewar flask, while for actual tests the material whose specific heat is to be measured is substituted for the specific heat standard. By use of this technique the specific heat of the capsule and the water equivalent of the Dewar flask are determined. Capsule transit time, radiation losses therein, and bath evaporation are maintained constant by strict routine and are included in the water equivalent calibration.

The test is conducted as follows: The specimen is packed into the thin-shelled capsule and the cap screwed or soldered on with a watertight fit. The capsule is weighed before and after this step, the difference in mass being the mass of the specimen, due account being taken of solder, if used. The capsule is then suspended centrally in the oven by a very fine wire and heated to an equilibrium temperature of the order of 100 C. above the temperature of the liquid bath in the Dewar flask. The heating time required is dependent upon the properties of the specimen and usually requires 3 to 5 hr., in order to reach thermal equilibrium. (It is desirable to have the apparatus in a room of low temperature drift.) When the capsule and contents are at thermal equilibrium, a measured mass of water (if temperature of capsule is less than 150 C.) is poured into the Dewar flask to a definite depth level. The depth level of liquid contents of the Dewar flask must be kept constant for all tests and for the calibration. The liquid bath is admitted at a few degrees above or below the desired bath temperature, depending upon whether the bath temperature is to be above or below room temperature. If the temperature of the heated capsule is above 150 C. the water should be replaced with some liquid of known specific heat and of higher boiling point. The differential thermometer and stirrer are then set into predetermined positions (constant for every run) and the stirrer set into motion. After a few minutes a constant thermal exchange will exist between the calorimeter and the environment, and the test is started.

The test actually consists of recording the temperature of the bath (read on the differential thermometer) for an initial period of 9 min. at 1-min. intervals. Then, on exactly the tenth minute no reading is made, but the capsule is dropped from the oven into the bath with a minimum of splash. Recording of temperature is resumed on the eleventh minute and continued at 1-min. intervals until the calorimeter and environment have been in constant thermal exchange for 10 min. (usually through the twenty-fifth minute). The thermal exchange which takes place in the tenth minute is considered instantaneous and is expressed mathematically as:

$$(M_s C_s + M_c C_c)(T_h - T_m) = (M_w C_w + E)(T_m - T_c)$$

where:

M_s = mass of specimen in g.,
C_s = mean specific heat of specimen between the limits of T_h and T_c,
M_c = mass of capsule in g.,
C_c = mean specific heat of capsule between the limits of T_h, and T_c,

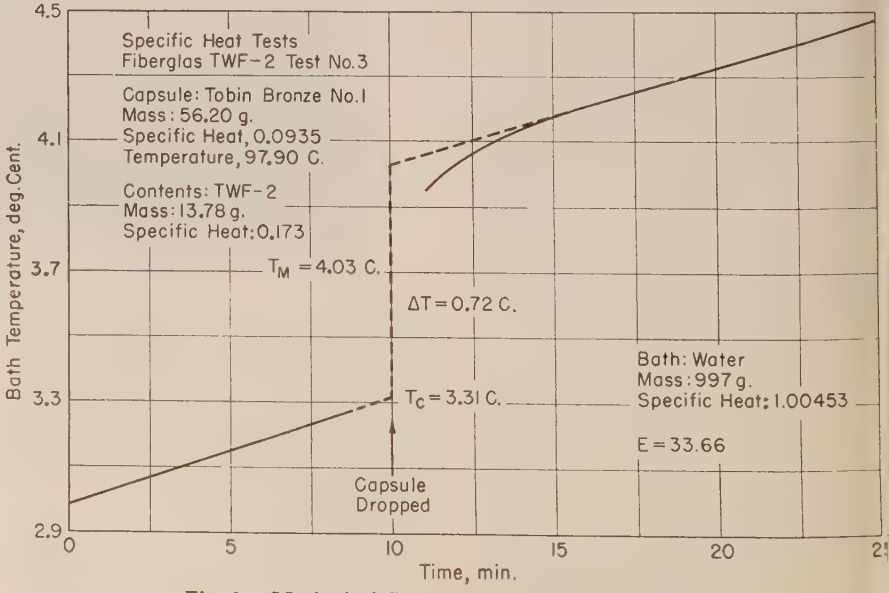

Fig. 2.—Method of Graphical Extrapolation of Data.

TABLE I.—MEASUREMENT OF SPECIFIC HEAT OF INSULATING MATERIALS; ROUND-ROBIN TRIALS OF PROPOSED TEST METHOD.[a]
(Material Tested: Fiberglas TWF-2.)[b]

Laboratory	Number of Test Run	Mass of Specimen, M_s, g.	Mass of Water Bath, M_w, g.	Water Equivalent, E, g.	Capsule		Temperature Changes, deg. Cent.		Reported Specific Heat, C_s, cal. per g. per deg. Cent.	Mean Value, C_s
					Material and C_c, cal. per g. per deg. Cent.	Mass, M_c, g.	Drop in Specimen, $T_h - T_m$	Rise in H_2O, $T_m - T_c$		
No. 1[c,e]	1	19.1390	2500	335^{+7}_{-8}	Brass	101.6173	94.395	0.487	0.2232	0.2187, *i.e.*, 0.22 ± 0.005
	2	19.1000	2500	335^{+7}_{-8}	0.1019 (msd.)	101.6173	93.905	0.475	0.2142	
No. 2[c,f,h]	1	24.7399	2500	80	Brass 0.0936 (calc.)	52.2846	101.17	0.370	0.1835	0.1882, *i.e.*, 0.19 ± 0.01
	2	24.7399	2500	80		52.2626	109.02	0.411	0.1954	
	3	24.7399	2500	80		52.2509	110.22	0.404	0.1845	
	4	24.7399	2500	80		52.2727	100.62	0.368	0.1836	
	5	24.7399	2500	80		52.2821	106.6	0.398	0.1915	
	6	24.7399	2500	80		52.2707	95.00	0.345	0.1809	
	7	24.7399	2500	80		52.2496	99.35	0.375	0.1959	
	8	24.7399	2500	80		52.2781	99.21	0.371	0.1921	
	9	24.7399	2500	80		52.3041	90.257	0.322	0.1857	
	10	24.7399	2500	80		52.2598	98.74	0.370	0.1930	
	11	24.7399	2500	80		59.5788	87.08	0.455	0.1845	
No. 3[d,g,i]	1	12.59	1003	33.66	Tobin Bronze 0.0935 (msd.) 0.092 (calc.)	56.20	93.87	0.72	0.194	0.180, *i.e.*, 0.18 ± 0.01
	2	14.09	1003	33.66		56.20	92.65	0.71	0.172	
	3	13.78	997	33.66		56.20	93.77	0.72	0.173	
No. 4	1	Bunsen Ice Calorimeter Measurements							0.1979	0.1983
	2								0.1987	

[a] Method proposed by Prof. E. B. Penrod, University of Kentucky, based on suggestion by Max Jakob; this is a simplified form of the classic Method of Mixtures. Its standardization is under jurisdiction of Subcommittee T-VII, A.S.T.M. Committee C-16.

[b] All specimens tested were deoiled material furnished from a single source (Owens-Corning Fiberglas Corporation), selected according to standard methods for random sampling.

[c] Dewar flask, 4-qt. capacity.

[d] Dewar flask, 1500-ml. capacity.

[e] Average of *four* determinations, using a 233.087-g. heated specimen of Cu (99.9 per cent pure) as a calibration standard (c_p calculated at 0.1011) dropped into water bath of test apparatus.

[f] "Rounded-up" value from average figure of 79.3 obtained by *two* calibration runs (79.2 and 81.2) using electrical heat-input method, and *one* run (77.5) using synthetic aluminum oxide c_p standard as furnished by the Bureau of Standards. This Al_2O_3 has a c_p value guaranteed to one part in 10,000.

[g] Average of *three* determinations, using a 13.5-g. heated specimen of Al_2O_3 (Bureau of Standards) in test capsule (c_c previously measured at 0.0935) dropped into water bath of test apparatus. These *three* determinations gave E's equal to 40.12, 38.56, and 22.21 g. E previously measured by three other determinations, using just the heated empty capsule (C_c *calculated* at 0.092), gave values of 41.48, 22.15, and 45.12, or 36.25 g. average, and was discarded as unreliable because of probable error in *calculated* C_c. Final C_c value (0.0935) of capsule was calculated by simultaneous solution of two equations averaging results by the Al_2O_3 and empty-capsule method with E and C_c treated as variables; E from this calculation was 36.55 g.

[h] Recorded weight of bare capsule 52.0916 in runs 1–4 and 6–10, inclusive, 52.0914 in run 5, and 59.3868 in run 11. Difference between these values and those in table represents weights of cut wire bales.

[i] Add 0.26 g. to tabular values of capsule weight to allow for weight of wire harness. Also, add in calculating C_c, weight of rubber gasket at 0.59 g., assumed specific heat = 0.42.

- T_h = temperature of capsule and contents after heating,
- T_m = temperature of mixture extrapolated back to t = 10 min.,
- T_c = temperature of bath liquid before capsule is dropped as extrapolated to t = 10 min.,
- M_w = mass of water or other bath liquid,
- C_w = mean specific heat of same between limits T_m and T_c, and
- E = water equivalent of Dewar flask and associated factors.

The temperatures of the bath are plotted against time, and the values of T_m and T_c determined by extrapolation as in Fig. 2. The known quantities are then substituted into the above equation and the specific heat computed.

Calibration of E and C_c are made by dropping the capsule, both empty and filled with a known specific heat standard such as synthetic sapphire,[6] and solving the resulting equations. The author has found that the synthetic sapphire may be replaced in calibration by $\frac{1}{4}$-in. aluminum alloy 17S-T4 spheres,[7] because other tests at this laboratory confirmed the specific heat data of this alloy.[8] This substitution has the advantage of unlimited volumetric displacements for calorimetry without unwarranted sacrifice of precision or stability of value. The aluminum alloy 17S-T4 spheres are an excellent secondary standard for specific heat, better than copper by virtue of greater conductivity per unit mass.

TABLE II.—RELATIVE SIGNIFICANCE OF TEST OBSERVATIONS AS POSSIBLE ERROR SOURCES.

Equation of Test: $C_s = \left[\frac{(M_w C_w + E)(T_m - T_c)}{T_h - T_m} - M_c C_c\right] \div M_s$

Quantity	Change	Amount	Per Cent Change of C_s for Laboratory		
			No. 1	No. 2	No. 3
T_m	+	0.01 C.	+7.08	+5.41	+8.09
E	+	10 per cent	+4.08	+0.66	+1.16
T_h	+	1 C.	−1.16	−1.99	−2.89
C_c	+	10 per cent	−2.37	−10.06	−21.97
T_c	+	0.01 C.	−7.03	−6.99	−1.16
M_w	+	10 per cent	+4.21	+1.99	+3.47
M_s	+	10 per cent	−10	−10	−10
M_c	+	10 per cent	−2.37	−10.06	−21.97

Results

The data from the three cooperating laboratories are shown in Table I, for the determinations of the specific heat of Fiberglas TWF-2. Also shown is a fourth laboratory report (National Bureau of Standards) which may be used as a reference for the true value. This value was obtained by use of a Bunsen ice calorimeter with reputed accuracy of 1 part in 10,000. The principal modification in the proposed test made by the three laboratories consists of use of a 2500-ml. calorimeter of relatively high heat capacity by laboratory No. 1, use of a 2500-ml. calorimeter of moderate heat capacity by laboratory No. 2, and use of a 1500-ml. lagged calorimeter of low heat capacity by laboratory No. 3. Laboratory No. 1 also used a capsule twice the mass of those used by the other laboratories. Each laboratory used a different method of calorimeter and capsule calibration.

The reported values deviate from the true values by 11, 5, and 9 per cent, respectively, the true values having a deviation of $\frac{1}{2}$ per cent. However, the mean of the reported values deviated from the true value by only 1 per cent. This demonstrates that the test method under consideration is potentially accurate.

The data submitted by the three cooperating laboratories have been analyzed to the extent that each variable of the basic test equation was varied a given amount or per cent and the per cent change in C_s calculated. The vari-

[6] D. C. Ginnings and R. J. Corruccini, "Enthalpy, Specific Heat and Entropy of Aluminum Oxide from 0 to 900 C.," *Journal of Research*, Nat. Bureau Standards, Vol. 38, No. 5, June, 1947, pp. 593–600 (*RP* 1797).

[7] Obtained from Hartford Steel Ball Co., Hartford, Conn.

[8] Aluminum Company of America, Pittsburgh, Pa.

ance was made from the standpoint of its feasibility and its weight in producing an error trend. For simplicity, a single test was selected at random from the data of each laboratory. These test runs were Nos. 1, 7, and 3, for laboratories No. 1, No. 2, and No. 3,[5] respectively.

The data of this analysis are shown in Table II in the order that they are most likely to occur in normal laboratory practice. Several distinct trends of deviation may be noted: First, mass measurements need little consideration from the standpoint of refined measurement, but accuracy of the test does depend upon selection of the relative masses. The trend indicates that selection of a lower M_w for purposes of obtaining greater temperature changes for a given test sample will render all measurements more critical, particularly the M_c. It is also seen that C_c is the most critical variable and therefore deserves the consideration of measurement rather than calculation. Temperature measurement or determination errors produce appreciable errors, particularly in T_m which is an extrapolated value. The water equivalent variance yields relatively smaller deviations as its value decreases with respect to M_w, and errors in its determination are not overly important in selection of a suitable calorimeter.

This short analysis possibly may appear to demonstrate that the proposed test is subject to considerable error. However, this is not true, since the large errors are results of exaggerated deviations that are not common to the measurements. As shown by the correlation of the mean value reported by the cooperating laboratories to the value reported by the National Bureau of Standards, the test is potentially accurate. It has a great advantage in its simplicity and ease of standardization, and requires now additional round-robin testing in cooperating laboratories in a modified form.

Acknowledgment:

The author takes pleasure in acknowledging the assistance of G. M. Rapp, Chairman of Subcommittee T-VII on Special Thermal Properties of Committee C-16 on Thermal Insulating Materials, for his contribution to this work and appreciated cooperation.

Discussion of a Paper on Tests for Air-Entraining Agents in Concrete[1]

Mr. John Siggelkow.[2]—The exceptionally good performance of certain of the non-air-entrained specimens referred to by the authors in the freezing-and-thawing tests would seem to give emphasis to the importance of the long-time study of cement performance in concrete now in progress by the Portland Cement Association. It is to be hoped that this study will point the way to continued improvement in the manufacture of cement.

But all of the non-air-entrained cements used in these tests met the A.S.T.M. specifications, and for the run-of-the-mill cements which the average engineer must count upon using for his structures these tests continue to show the great advantage of air entrainment in improving the freezing-and-thawing resistance of concrete. The remainder of this discussion will apply to air-entrained concretes only.

The authors indicate the "greater durability for the 4½- than for the 6-sack concretes" and in this connection they state that "durability of concrete in freezing and thawing is primarily dependent upon the percentage of voids filled with water at the time freezing takes place."

Let us examine the subject tests, and others, for support or qualification of this statement, and for such other information as may develop.

Assuming that the "voids" in concrete consist of air and water, then it follows that the ratio of air content to air plus water content is the ratio with which we are here concerned. This will be expressed as $A/(A + W)$, in which A and W are the quantities of air and water, respectively, present in the fresh mix, in cubic feet per cubic yard.

The resistance to freezing-and-thawing influence as measured by the loss in dynamic modulus is sometimes expressed as *DFE*, which considers the number of cycles as well as the dynamic loss. (It will be understood, of course, that high *DFE* values represent great freezing-and-thawing resistances.) Those computed by the writer for the subject tests are somewhat rough but are believed to present a fair comparison of the freezing-and-thawing resistances of the concretes within the series. For other test series examined, the *DFE* computed by those investigators will be used.

Let us now consider air-entrained concretes tested at an age not greater than two months. The data in the accompanying tables are arranged in ascending order of the value of the ratio $A/(A + W)$.

The information given in Tables I and II is from a paper by C. E. Wuerpel[3] while the information given in Table III is taken from a paper by F. B.

TABLE I.—AIR-ENTRAINED CONCRETE.

First phase—Cured in fog 14 days, tested at 16 days. No soaking period noted. 250 fast cycles of freezing and thawing in water.

Admixture	$A/(A + W)$	Dynamic Modulus Durability Factor	Cement, bags per cu. yd.
T.....	0.17	72	4.5
T.....	0.18	78	6.0
T.....	0.19	77	5.25
Average.....	0.18	76	....
Average[a]...	0.28	86	6.0
	0.31	83	4.5
	0.34	85	5.25
Average.....	0.31	85	....

[a] Average of other admixtures closely grouped as to air entrained and performance in tests.

TABLE II.—AIR-ENTRAINED CONCRETE.

Second phase—No soaking period noted. 250 fast cycles of freezing and thawing in water. Various admixtures.

$A/(A + W)$	Dynamic Modulus Durability Factor		Cement, bags per cu. yd.
	9-day Specimens[a]	28-day Specimens[b]	
0.21..	76.5	52	6.0
0.21..	87	86.5	6.0
0.21..	92.5	91.5	6.0
0.21..	94	95	6.0
0.22..	82	62	6.0
0.22..	88	83.5	6.0
0.23..	63	57	4.5
0.24..	69	49	4.5
0.24..	89	73.5	4.5
Avg. 0.221.	82.3	72.2	5.50
0.25..	91	92.5	6.0
0.25..	92	93.5	6.0
0.27..	89	80	4.5
0.27..	91.5	82	4.5
0.28..	92	82	4.5
0.29..	93.5	88	4.5
0.32..	92	82	4.5
0.33..	83	79	6.0
Avg. 0.283.	90.5	84.9	5.06
0.38	91	91	6.0
0.41..	86	79	4.5
0.41..	82	78	4.5
Avg. 0.40..	86.3	82.7	5.0

[a] 9-day specimens cured in fog 7 days, tested at 9 days.

[b] 28-day specimens cured in fog 26 days, tested at 28 days.

[1] G. W. Washa, C. H. Scholer, D. W. Lewis, and N. H. Withy, "Tests for Air-Entraining Agents in Cement and Concrete," ASTM Bulletin, No. 163, January, 1950, p. 61 (TP11).

[2] Assistant Civil Engineer, Westchester County Department of Public Works, White Plains, N. Y.

[3] C. E. Wuerpel, "Laboratory Studies of Concrete Containing Air-Entraining Admixtures," *Journal*, Am. Concrete Inst., Vol. 17, No. 4, February, 1946; *Proceedings*, Vol. 42, p. 305.

ornibrook.[4] In Table I the specimens ere fog cured for 14 days and tested 16 days. As shown in Table II the day specimens were fog cured for 7 ays and tested at 9 days, while the 28- ay specimens were fog cured for 26 ays and tested at 28 days. From the ble prepared from the Hornibrook tests Table III) it will be noted that the ecimens were fog cured for 14 days, lowed to soak for 1 day, then followed y freezing-and-thawing tests to a 25 per nt drop in dynamic modulus or to 160 cles.

ABLE III CONCRETE CONTAINING DMIXTURE PRINCIPALLY OF THE AIR-ENTRAINING TYPE.

Specimens cured in fog 14 days, one day soak- g, followed by freezing-and-thawing tests to per cent drop in dynamic modulus or to 160 cles. Various admixtures.

$A/(A + W)$	Dynamic Modulus Durability Factor	Cement, bags per cu. yd.	Saturation Coefficient
0.086.	20	7	95
0.09..	7	5.5	94
0.095.	13	5.5	92
0.105.	35	7	95
0.11..	95	7	89
0.12..	12	5.5	89
0.13..	22	7	90
0.14..	89	7	90
0.17..	15	5.5	85
0.17..	62	5.5	85
0.21..	42	5.5	76
0.25..	60	7	80
0.25..	92	5.5	78
0.26..	64	7	79
vg. 0.156.	44.9	...	86.9
0.265	99	7	81
0.275.	93	7	89
0.28..	96	7	74
0.284.	93	7	87
0.29..	79	5.5	86
0.30..	91	5.5	68
0.31..	67	5.5	67
0.33..	85	7	62
0.33..	91	7	58
0.33..	96	5.5	66
0.34..	91	5.5	76
0.34..	99	5.5	47
0.38..	96	7	78
vg. 0.312.	90.5	...	72.2
0.40..	56	7	67
0.40..	87	5.5	76
0.40..	90	7	60
0.40..	93	5.5	60
0.41..	78	5.5	57
0.41..	88	5.5	54
0.43..	83	5.5	38
0.44..	90	7	47
0.46..	81	5.5	74
vg. 0.416	82.9	...	59.2

ABLE IV.—GROUP II AIR-ENTRAINED CONCRETES.

Cement types IA and IIA, Admixture N-Tair ecimens moist cured 14 days, cure continued air 2 to 3 weeks. Soaked 5 days half immersed water followed by freeze-thaw tests, first 200 cles frozen in air, thawed in water, additional cles freezing and thawing in water. Water ange, per cent by volume of concrete, between d of curing and start of freezing and thawing.

$/(A + W)$	Dynamic Modulus Durability Factor	Cement, bags per cu. yd.	Water Change
0.20...	6.2	5.98	+2.6
0.21...	8.0	5.98	+2.8
0.21...	10.5	6.00	+1.8
0.21...	25.0	6.01	−1.7
vg. 0.21...	12.4	...	+1.4
0.27...	27	4.48	+0.3
0.28...	88	4.49	+0.2
0.29...	21.9	4.49	−1.8
0.29...	88	4.50	−0.7
vg. 0.28...	56.2	...	−0.5

From the foregoing tests, it seems reasonable to infer that for concretes at these early ages the freezing-and-thawing resistance increases with the value of the ratio $A/(A + W)$ and that the greater the soaking period prior to test the greater are the relative differences in the freezing-and-thawing resistances.

It also seems reasonable to infer that for comparable conditions of curing, saturation, and freezing, the value of this ratio should preferably be 0.30 ± 0.03.

The degree of saturation as a result of soaking also appears to be a function of the ratio $A/(A + W)$ as indicated in Tables III and IV.

TABLE V.—GROUP I AIR-ENTRAINED CONCRETES.

Cements types I and IA. Admixtures N-Tair and Darex. Specimens moist cured 14 days, stored 6 months in air, then immersed in water 3 days, followed by freezing-and-thawing tests.

$A/(A + W)$	Dynamic Modulus Durability Factor	Cement, bags per cu. yd.
0.16....	20.0	6.64
0.19....	45.5	6.64
0.21....	26.6	4.05
0.22....	29.0	4.99
Avg. 0.195...	30.3	...
0.23....	29.0	4.99
0.23....	20.0	5.01
0.26....	21.3	3.98
Avg. 0.24....	23.4	...

Since the saturation or water gain increases when the value of the ratio $A/(A + W)$ is low and this in turn reduces the freezing-and-thawing resistance, it would appear that the statement quoted near the beginning of this discussion is amply substantiated as applied to concretes at an early age.

This, of course, does not preclude the possibility that other properties of air-entrainment may be at work in producing the above results.

Now let us consider those concretes tested in the present series at 6 months, with respect to the data in Tables V and VI.

[4] F. B. Hornibrook, H. Freiberger, and A. Litvin, "A Study of Durability and Void Characteristics of Concretes Containing Admixtures, Principally of the Air-Entraining Type," *Proceedings*, Am. Soc. Testing Mats., Vol. 46, pp. 1320–1332 (1946).

From Tables V and VI it seems reasonable to infer that at 6 months age, with no saturation of the specimens until the end of that time, the effect of the ratio $A/(A + W)$ is no longer of great importance and that with appropriate air contents the higher strength concretes will have the greater freezing-and-thawing resistance.

Summary:

1. For air-entrained concretes subject to saturation at an early age, followed by freezing and thawing the ratio $A/(A + W)$ should have a value of approximately 0.30 in the fresh concrete.

2. For air-entrained concretes reaching the age of 6 months or more without saturation the $A/(A + W)$ ratio is unimportant and the freezing-and-thawing resistance is a function of a combination of strength with appropriate air entrainment.

MR. G. W. WASHA (*authors' closure*)—The authors have read with interest the discussion by John Siggelkow, and wish to call attention to the fact that Mr. Siggelkow has discussed the problem on the basis of the $A/(A + W)$ ratio for fresh concrete, whereas the authors have based their discussion on the relative void space in the hardened concrete at the start of the freezing and thawing.

The approach to the analysis of the freezing-and-thawing problem suggested by Mr. Siggelkow appears to have merit. If a critical value of about 0.30 for the ratio $A/(A + W)$ could be substantiated by further comprehensive study, an important new approach of considerable value would be available for the design of durable concrete.

Since item 2 in the summary of the discussion is based on a limited number of tests (group I of our paper), its significance may be open to question unless additional supporting data can be provided.

TABLE VI.—AVERAGES FOR EACH CEMENT CONTENT.

Same specimens as in Table V. A, W, and C are the absolute volumes of air, water, and cement, respectively, per cu yd.

Cement, bags per cu. yd.	Air, per cent	Water, cu. ft. per cu. yd.	$(A + W)/C$	Dynamic Modulus Durability Factor	$A/(A + W)$
6.6.....	3.3	4.11	1.57	32.8	0.175
5.....	4.3	4.00	2.15	26.0	0.227
4.....	4.9	4.23	2.88	24.0	0.235

LABORATORY SUPPLIES . . .

Catalogs and Literature and Notes on New or Improved Apparatus

Note—This information is based on literature and statements from apparatus manufacturers and laboratory supply houses.

Catalogs and Literature

Acme Laboratory Equipment Co., 506 W. 124th St., New York 27, N. Y. The new 24-page Catalog No. 50 lists a line of hospital and laboratory equipment in stainless steel including autoclaves, water baths, ovens, pipette washers, and shakers.

The Baldwin Locomotive Works, Testing Equipment Department, Philadelphia 42, Pa., Bulletin 310 describes the new, low-cost Model 60-H Baldwin-Sonntag universal testing machine of 60,000 lb. capacity. This four-page bulletin explains and illustrates the operation of the testing machine, its controls and accessories, emphasizes its features, and gives specifications.

Bulletin 313 describes the Model SF-4 Sonntag fatigue machine of ±5000 lb. capacity. This two-page bulletin tells how the testing machine works, gives specifications, and contains illustrations showing both external and internal equipment, controls, and operating mechanism.

Hagan Corp., 323 Fourth Ave., Pittsburgh, Pa. The Hagan Meter Type Differential Master Sender, a pneumatic machine used as the metering element in the measurement and control of steam, gas and liquid flow, liquid level, pressure differential and similar applications, is described and illustrated in the four-page Bulletin 2150. The Master Sender is characterized by instantaneous response to all changes in applied differential and provides precise measurement over a continuous range from 50 in. water column to 150 psi. at static pressures up to 2500 psi.

Parr Instrument Co., 211 Fifty-third St., Moline, Ill. The new 48-page instruction manual for the Parr sodium peroxide combustion bombs contains operating instructions for the macro, semimicro, and micro Parr peroxide bombs, together with an extensive bibliography and summaries of many important analytical tests in which these bombs are used. Replacing the former Manual No. 116, copies of the new Manual No. 121 will be supplied through Parr dealers on request, or may be obtained by writing direct to the company.

Riehle Testing Machines Division, American Machine and Metals, Inc., East Moline, Ill. Two new catalogs on Riehle Testing Machines are now being offered by the manufacturer. Catalog RC-2-50 covers Hydraulic Compression Testing Machines and other equipment for testing concrete, brick, tile, and other construction materials. Catalog RU-3-50 describes the new low-cost Model MA Universal Hydraulic Testing Machines. Both catalogs are profusely illustrated and include details of construction, specifications, and dimensions.

E. H. Sargent & Co., 4647 W. Foster Ave., Chicago 30, Ill. "Scientific Apparatus & Methods" (including latest catalog revisions—Volume 3, Spring, 1950) includes in its Section I on Scientific Methods an article on the Polarography of Vitamins and a well-illustrated article on its new Chicago plant and offices. Section II on Scientific Apparatus covers new, reinstated, and discontinued items, and changes in specifications.

Instrument Notes

Coordinate Cathetometer—The Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago 14, Ill. This instrument is for measuring horizontal and vertical displacements through a 4 by 4-in. range. Observations are made through a telemicroscope having a mechanical working distance adjustable from about 5½ in. to infinity. For shorter working distances, a microscope can be substituted. Measurements are made by divided drums attached to precision lead screws. Accuracy of measurements is governed by the working distance, being greater at shorter distances. The micrometer drums are readable to 0.0001-in. It can also be supplied with metric screws and scales.

Podbielniak Hyd-Robot Analyzer—Minneapolis-Honeywell Regulator Co., Industrial Division, Philadelphia 44, Pa. This is an automatic, low-temperature distillation apparatus, applicable to routine or research analysis. Instrumentation, and various mechanical, hydraulic, and electrical mechanisms, working between adjustable limits, provide complete control of all low-temperature distillation variables.

Electronik Differential Recorder—Minneapolis-Honeywell Regulator Co. By using this instrument, qualitative and quantitative analysis of mineral mixtures is said to be speeded up and made more positive through the use of a differential thermal analysis technique. This analytical method is based on a study of the exothermic and endothermic reactions which take place when a mineral is heated. The temperature and direction at which this reaction occurs serve to identify the material, while the amount of heat change gives a measure of the quantity of the material involved.

Oxygen Bomb—Schutte & Koerting Co., 12th and Thompson Sts., Philadelphia, Pa. This was developed in conjunction with the engineers of the Du Pont Rubber laboratories. As safety is of paramount importance, the bomb has been made extra heavy with ample factors of safety in all parts. It is furnished complete with electric water heater, sensitive automatic temperature controller with relay, pressure gage, recording thermometer, water supply tank, and the interconnecting piping and fittings; the oxygen is supplied to the bomb at 400 psi.

Light-Scattering Microphotometer—American Instrument Co., Inc., Silver Spring, Md. This new instrument measures 20 micromicrolumens of scattered light, has a sensitivity approximately 100 times greater than similar instruments. It may be used with any of the accepted techniques for molecular weight, particle size, microfluorescence, depolarization, dissymmetry, and microturbidity measurements. Its high sensitivity opens new fields in the measurement of optical-glass scattering power and in microchemical turbidity analyses. Portable and completely a-c. operated, it employs two built-in electronic-regulated power supplies, also a d-c. amplifier which operates the panel microammeter and which may be connected directly to an external recorder. Full-scale deflections of the panel microammeter are made with photomultiplier tube currents of 10, 1, 0.1, and 0.01 microamperes. Details are given in Bulletin 2182, obtainable upon request.

Tungsten Carbide Pencil—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa. This pencil for permanently marking glassware is available for a variety of laboratory tasks: sealed vials of standard colorimetric samples can be permanently identified; sheets of glass may be accurately scored for breaking; tubes and rods can be scored more rapidly than with a file. The tungsten carbide point is permanently mounted in a knurled steel pencil shaft and is protected by a cap so the pencil may be safely carried in the pocket, ready for use.

The Fluoretor—Menlo Research Lab., P. O. Box CQ, Menlo Park, Calif. For the nondestructive testing of structures, weldments, vessels, and other objects too large for transport to a permanently installed black-light booth, this instrument combines portability and self-powered operation with facilities to permit observation under intense ambient light. Two standard Size D flashlight batteries supply power for the ultraviolet generator which is attached by a swivel joint to the wand-type handle containing power components. A light-tight dark chamber fits around the generator head to exclude light from the area under examination. A sponge rubber cone improves the light seal on rough or irregular surfaces. A series of specimen-holding end caps fits the mouth of the dark chamber so small objects can be examined without removing them to a darkened area. A focusing eyepiece provides 3 *X* magnification for the observer. Alternative generator-filter heads are available for operation at either 2537 or 3660 Ångströms.

The Varicell—The Superior Electric Co., Bristol, Conn. This new product which was developed "to meet the demand for a single instrument that would provide stabilized and regulated variable d-c. voltage from a-c. power lines." Literature available on request explains in detail the workings of the Varicell and its operation. A circuit drawing illustrates how the Varicell operates. Ratings, outline dimensions, stabilization, and regulation data are also included.

Explosionproof Variable Transformers—The Superior Electric Co., Hannon Ave., Bristol, Conn. The new Explosionproof Powerstats provide a safe means of obtaining a continuously adjustable source of a-c. voltage in hazardous areas where a small arc or spark could cause an explosion. They consist of a Powerstat variable transformer totally enclosed in a case which will withstand internal gas or vapor explosions. At the same time, the case is designed to

prevent the ignition by internal spark, flash, or explosion of the gas or vapor surrounding the enclosure—assuring complete protection. They are Underwriters' approved for Class 1, Group D service. Various types are available in 115- and 230-volt ratings for single-phase operation.

Force Indicators—Hunter Spring Co., Lansdale, Pa. The Apparatus Division has increased its line of Force Indicators to 12 models. In addition to the original model (of 10 lb. maximum capacity) it now is available in capacities of 1, 2, 5, and 20 lb.; 16, 32, 80, and 160 oz.; and 500, 1000, and 5000 g. The Force Indicator uses a compensated spring mechanism (gradient error is as small as 0.1 per cent) and a fully jeweled dial indicator to measure and indicate force. It is useful for checking forces and pressures in various mechanisms and instruments.

Motor-Driven Cement Flow Table—American Instrument Co., Inc. A new 10-in. diameter motor-driven flow table for testing the flow (consistency) of portland cement, meeting A.S.T.M. specifications is available. The complete apparatus consists essentially of the latest design of 10-in. diameter flow table, motor drive, and bracket for mounting on a concrete pedestal. The motor drive and its mounting bracket may be purchased separately for attachment to manually operated flow tables presently in use.

New Weather-Ometer—Atlas Electric Devices Co., 361 W. Superior St., Chicago, Ill. A new Weather-Ometer, Type XW, is a completely redesigned and modernized version of the Model X-1-A into which has been incorporated many new features employed for the first time in any weathering machine. The capacity of the Type XW is 54 specimens—each measuring 3 by 9 in. and providing for a continuous burning time of 16 to 18 per trim of its carbon electrodes as its source of radiation.

Dynamic Strain Amplifier—The Baldwin Locomotive Works, Philadelphia 42, Pa. This new type, portable strain amplifier is designed for use with any standard cathode ray oscilloscope to measure almost any mechanical reaction detected by SR-4 bonded resistance wire strain gages. Data may be recorded by means of either special high-speed cameras or an ordinary still camera without shutter.

Fisher-Goldman Mixer—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa. This new mixer is designed to break up whirlpool action to produce both horizontal and vertical mixing. It is claimed the mixer can be used for liquid-liquid, liquid-solid, or liquid-gaseous dispersions. The mixer employs slightly curved, rotating paddles, adjustable for different viscosities, to effect the actual agitation.

A-C Resistance Boxes—Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa. These new resistance boxes are designed for use as moderate-precision, adjustable standards for d-c. and a-c. resistance measurements up to medium frequencies. Principal feature of the boxes is an entirely new type of rotary switch having exceptionally low and stable contact resistance, obtained through the use of solid silver switch contacts and silver alloy multiple-leaf brushes. Zero or contact resistance is less than 0.002 ohm per decade and changes less than 0.0005 ohm per decade on accelerated life tests.

Electrically Heated Laboratory Dryer—Proctor & Schwartz, Inc., Seventh St. and Tabor Road, Philadelphia 20, Pa. The wide possible application of this electrically heated laboratory dryer makes it fit into the picture of any laboratory process. It is suited to the drying of samples or small quantities of a wide variety of materials that may be loaded on trays or hung on rods or hooks. Whenever necessary, the entire heating unit can be removed in one section. Drying temperatures as high as 300 F. may be employed. This laboratory dryer has wide application in the chemical, pharmaceutical, food and textile field.

Combination Flask-Separatory Funnel—Scientific Glass Apparatus Co., Inc., Bloomfield, N. J. The new, Hustinx, heatable flask-separatory funnel with stopcocks and made of "Pyrex" brand glass is ideal for general laboratory work, and saves considerable time and material in analytical and synthetic operations. It may be used for carrying out many chemical operations without the necessity of transferring to other flasks and may also be used as a separatory funnel for both light and heavy liquids; for determining the fatty acid content of soaps; and for operations which must be carried out in the presence of an inert gas.

Transet Recorder—Taylor Instrument Cos., 95 Ames St., Rochester, N. Y. This new miniature recording-receiving instrument for pneumatic transmission of flow, liquid level, pressure, and temperature was developed to meet the rapid, widespread demand for process information at a central point, requiring pneumatic transmission. With conventional-sized receivers, control rooms often become large and confusing; this pointed the way to graphic panels and to a small recorder to provide the needed processing data right on the panel itself.

Tempilstik—Tempil Corp., 132 W. 22nd St., New York 11, N. Y. Tempilstiks have a sharp, rapid melting action at predetermined temperatures. They are said to provide an inexpensive and accurate way of determining industrial temperatures.

Machinability Tester—Vanton Equipment Corp., Empire State Building, New York 1, N. Y. A simple workshop unit for testing machinability of ferrous and nonferrous metals, the tester investigates two basic characteristics of metals: (1) it measures the specific cutting resistance exerted by a material against the penetration of a standardized kind and shape of cutting tool, the measurement being indicated on the instrument dial in pounds per 0.001 sq. in.; (2) it measures the abrasiveness effect of the same work material on a hardened calibrator. Machinability index is Specific Cutting Resistance multiplied by Abrasion Factor. These factors can be reproducible anywhere under the same general conditions.

Dual-Purpose Laboratory Bath—American Instrument Co., Inc., Silver Spring, Md. A new dual-purpose constant temperature bath described can be used as a precisely controlled temperature through external apparatus such as refractometers, polarimeters, viscometers, spectrometers, etc. The temperature of the bath or the circulating fluid is held constant within ±0.03 C. at any temperature from 6 C. above ambient to +95 C. if water is used as the bath fluid or circulant, and up to 150 C. if oil is used. By using a cooling coil in the bath, minimum temperature can be maintained at approximately 6 C. below ambient. The liquid capacity of the bath is 3 gal., and the bath is small and light enough to be easily portable.

Molykote—The Alpha Corporation, Greenwich, Conn. A smooth-textured, molybdenum disulfide powder, it is a dry lubricant with a very low coefficient of friction. One suggested use is in connection with testing machine grips.

Aminco Electronic Relay—American Instrument Co., Inc., Silver Spring, Md. This had been designed for a wide range of applications, typical of which are power control from delicate contact-making instruments, thermoregulator and similar instruments, when contact current, wear, and deterioration are important factors. Other applications include actuation of motors, valves, alarms from photocells, thermal sensitive resistors, chemical solution, etc.

INSTRUMENT COMPANY NEWS . . . .

Announcements, changes in personnel, new plants and locations, and other notes of interest

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SPERRY Products, Inc., Danbury, Conn., announces the appointment of Charles T. Morgan, 21 Lothrop St., Beverly, Mass., as manufacturer's representative in eastern New England, covering the following products: nondestructive ultrasonic testing instruments, including the Reflectoscope and Reflectogage; hydraulic remote controls; self-sealing couplings; and transformers. It was also announced that George D. Demougeot has been appointed plant manager. He was formerly plant manager of the Ronson Art Metal Works, Inc., Watson Flagg, and Fairchild Engine & Airplane Corp.

PHILIP JOHNSTON has been appointed Sales Manager of Riehle Testing Machines Division, American Machine and Metals, Inc., East Moline, Ill. Mr. Johnston will make his headquarters at the company's factory and general sales offices in East Moline.

MALCOLM L. HALL has been appointed Manager, Testing Equipment Department, The Baldwin Locomotive Works, Eddystone, Pa., in which capacity he will have complete responsibility for the operation of this phase of Baldwin's activities. In 1947 Mr. Hall was made Sales Manager, Testing Equipment Department of Baldwin, at Eddystone, Pa., which position he held until his recent appointment.

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